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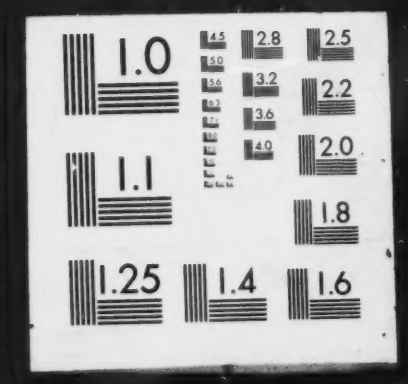

U.S. DEPARTMENT OF COMMERCE
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Urban Travel Forecasting

NATO Committee on the Challenges of Modern Society, Brussels (Belgium)

Jun 78

PBRU-103005

Committee on
the Challenges of
Modern Society

URBAN TRAVEL FORECASTING

The NATO/CCMS

Urban Transportation Pilot Study

CCMS REPORT NO. 87

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16. ABSTRACT

This study deals with one of the areas in urban transportation and it is potentially useful to governments that are facing difficult decisions regarding alternative transportation investments.

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INTRODUCTION

FRAMEWORK FOR THE SUBPROJECT

This subproject is one of five problem areas in urban transportation that are being studied under the North Atlantic Treaty Organization/Committee on the Challenges of Modern Society (NATO/CCMS) Urban Transportation Pilot Study. Since its inception a number of pilot projects have been undertaken cooperatively by NATO allies, all aimed at various areas of social and environmental concern. Urban transportation as a new area of investigation was introduced by the United States at a 1971 NATO/CCMS Plenary Session and specific proposals made at the 1972 Spring Plenary. In September of that year a committee of experts was convened to consider five possible subprojects which were presented to the North Atlantic Council at the Fall 1972 Plenary. The Council approved the Urban Transportation Pilot Study in December 1972.

An organizational meeting of experts for the Travel Forecasting Subproject was held in June 1973. Countries represented were Belgium, the Federal Republic of Germany, the Netherlands and the United Kingdom, in addition to the United States.* A proposed study design for the Travel Forecasting Subproject was discussed and alternative project approaches were considered. Subsequent suggestions by the participating nations

* While expressing a keen interest in this project, the delegate from Belgium subsequently had to withdraw because of commitments in other subprojects.

concerning the approaches for analysis have enhanced and strengthened the applicability of the project to meeting the CCMS goals.

As with other projects under the NATO/CCMS sponsorship, this study was chosen because of its potential for being directly useful to governments and policymakers facing difficult decisions regarding alternative transportation investments. The project relies extensively on recent and existing knowledge and readily available data sets for analysis purposes. In addition a finite project duration could be achieved. While this subproject treats only one element (trip generation) of a number of travel demand estimation aspects, the results appear promising, giving rise to the thought that further investigation in this subject area might be beneficial.

Participants in the Study

This subproject was a cooperative effort among the participating nations in an area of mutual concern. The following expert delegates provided input into this project: (1) Irs. Hoekwater and Bexelius of the Rijkswaterstaat, Netherlands; (2) Miss Anne Marsden of the Department of the Environment, United Kingdom; (3) Dr. Hans-Peter Weber and Mr. Rolf-Peter Eisele of the Bundesverkehrsministerium, Federal Republic of Germany; and (4) Mr. Christopher R. Fleet, U.S. Department of Transportation, Federal Highway Administration.

THE CURRENT PROBLEM

Public officials and decision-makers are more and more often being required to evaluate alternative courses of action and investment dealing with transportation services. The economic and social implications of such actions demand that the decision-maker have at hand the best and most efficient tools to aid him in making those decisions. The manifold facets and complexities of urban growth in recent years has made the transportation planner and analyst's job of providing those tools, and the resulting information, to the decision maker overly difficult.

Until recently the planner has had to respond to question about the rate and direction of growth in the demand for transport services. This has generally been in an environment when growth has been viewed as an unmitigated good. More recently, however, attitudes toward growth and uncontrolled urban expansion have drastically changed and have become an international concern. Consequently, the questions that officials are asking of the planners and forecasters today have changed. More often than not, today's urban transportation planner is being asked to determine the consequences of not making a certain transportation investment rather than to determine what investments need to be made to meet the otherwise unconstrained demand for transport services.

There is another situation which gives particular emphasis to this project. By simplifying and achieving a degree of standardization in travel estimation procedures, benefits could accrue to the user nations in the form of time and cost savings as well as broadening the spectrum of conditions under which the forecasting procedure can be expected to operate. The first benefit could result from the application of a less sophisticated, and therefore less costly, forecasting procedure. The latter benefit could result in a cross fertilization of knowledge regarding the consequences of various policy decisions. North American cities can be characterized as relatively low in density, high in auto ownership, and low to moderate in public transit usage. European cities, on the other hand, are generally higher in density, lower in auto ownership, and demonstrate a correspondingly higher transit usage. Under these circumstances, the desirability of a generalized simple and efficient forecasting procedure, suitable for application to a broad range of conditions has become greatly heightened.

Changes in the Urban Complex And Its Effect on Travel

In examining the changes that have taken place in urban regions and those that are likely to occur in the future, it is useful to contrast the European and U.S. condition and experience. The general nature of European cities with regard to development patterns has been largely a result of public policies that have encouraged higher densities and more compact cities. Geographic limitations have also tended to have their effect in many cases. The relative luxury of available land for expansion experienced in the past by the U.S. is not common among European nations. Population densities are on the order of 10 to 20 to 1 when compared to the overall density of the U.S.

	Population/Square Mile	
Country	1967 1/	1970 2/
Germany	623	619
Netherlands	970	1001
United Kingdom	585	591
United States	54	56

The largest percentage of an industrial nation's population is found in urban areas.

1/ "Trends in Motorization and Highway Programs in 16 European Countries," International Road Federation, Washington, D.C., 1969.

2/ Area from reference 1/ and population from "Statistical Yearbook, 1971," United Nations, New York, 1972.

Country	Urban Population as a Percent of Total	
	1960[3]	1970[4]
Germany	76.4	80
Netherlands	80.0	78
United Kingdom	78.5	78
United States	70.0	74

There are, however, indications that urban growth in Europe may be beginning to subside. Bouladon states that most European towns are now "full up" and that the reasons for the accelerated growth over the past 150 years, migration of agricultural population and overall population growth are diminishing in importance.[5] Where the migration from the country to the town was about 35 percent from 1900 to 1973, it will now be closer to 5 to 6 percent. Dr. Bouladon also cites the shift in population growth in Europe from an average of about 1 percent per year over the last 50 years to 0.54 percent today.* Thus, Dr. Bouladon concludes "we have a city with a slow growth rate in which the urban area must be rearranged so as to make it more 'natural'--more agreeable for the citizens."[6]

In this regard Plowden indicates that British problems are more a result of rising incomes and auto ownership than urban growth itself,

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[3] "Growth of the World's Urban and Rural Population, 1920-2000," United Nations, New York, 1969.

[4] For Netherlands and U.K.: "1973 Demographic Yearbook," United Nations, New York, 1974. For Germany: "1972 Statistical Yearbook," United Nations, New York, 1973.

[5] Bouladon, Gabriel, "Man, The City, and The Automobile in the Future," Futures, February 1974, pp. 59-64.

* Represents nine EEC Countries over the past 5 years.[5]

[6] Bouladon, Gabriel, op. cit.

although the two forces are certainly not independent.7/ He concludes that the British situation does not require alternatives for extending transportation systems geographically, but a study of alternative ways to replace systems that have ceased to function properly.

U.S. experience has generally been one of extension of transport systems geographically to keep pace with the rapid growth in the suburbs and the spread of urbanized areas. Each year urban America is spreading at the rate of a million acres. 8/ While the population in urban areas has increased dramatically in the U.S. (24% from 1960 to 1970 while that for the U.S. as a whole was 13%), the geographical extent of urbanized areas has also grown so that urban densities have decreased from 5,400 people per square mile in 1950 to 3,376 in 1970.

Although not generally as pronounced as portrayed by Bouladon for Europe, there are indications more recently that the urban growth pendulum may be starting to swing the other way in the U.S. According to the U.S. Bureau of the Census almost one million more people moved away from metropolitan areas than into them between 1970 and 1973. Also the large decreases of central city population experienced in the past have ebbed slightly.

7/ Plowden, S.P.C., "Transportation Studies Examined," Journal of Transport Economics and Policy, Vol. I, No. 1, January 1967, p. 10.

8/ Owen, Wilfred, "The Metropolitan Transportation Problem," The Brookings Institution, Washington, D.C. 2nd. 1966.

While these shifts are apparently small, the implication for urban development and changing transportation needs is important. Transportation systems in the past in both Europe and the U.S. have been responsible for allowing high concentrations of people in limited areas. Rapid rail and mass transit lines concentrated in radial directions helped bring people into the central city. The growth of the automobile and resulting growth in travel, however, has resulted in a spread of population and employment centers. This has been much more prevalent in the U.S. than in European nations. To a great degree public policy in Europe has been such that it has tended to influence both the ownership of an auto and its operation. This is illustrated by the 1973 figures in the following table:

TABLE 1

1973 AUTO OWNERSHIP AND TRAVEL STATISTICS

Country	Autos/Cap.	Annual Auto Vehicle-Miles Per Capita	Annual Auto Vehicle-Miles Per Auto	Annual Gas Consumption Gal. Per Cap.	Minimum Price Regular Gas $US/Gal.	1974 Premium Gas Cost $US/Gal.
Germany	.275	2,425	8,824	106.6	1.21	1.33
Netherlands	.240	2,423**	10,067	94.5	1.07	1.11
Great Britain	.248	2,197	8,855	111.2	0.81	.97
United States	.469*	4,696*	10,129*	472.3*	0.36*	.55

* 1972

** Based on estimated 1973 vehicle-kilometers

Sources: "World Road Statistics, 1969-1973," 1974 Ed., International Road Federation, Washington, D.C.

1974 gas prices: O.E.C.D. April 1974.

Ownership and use of a car in Europe is expensive, and total per capita auto travel is less than in the U.S. On a per-car basis the car in Europe is driven about as many or more kilometers per year on the average than the American car.

Country	1972 Average Annual Kilometers 9/
Germany	14,400
Netherlands	16,400
Great Britain	14,400
United States	16,300

Even though cars have long been heavily taxed,* along with fuel, in Europe this has apparently not reduced the desire to use the automobile for those who have one.

Land development policies which have encouraged higher densities have also had an influence on travel by allowing greater accessibility to transit. Transit accounts for only about 5.5 percent of the total person trips to work in Los Angeles, one of the least dense urban areas in the world, while it accounts for as much as 40 to 50 percent in a few very large cities (e.g., 47% in New York10/ and London10a/). An example of the relationship

---

9/ "World Road Statistics, 1969-1973," International Road Federation, Washington, D.C., 1974.

*For example private cars purchased in the Netherlands are subject to a tax of 15% of the selling price. In Great Britain the tax can be as high as 36.7 percent of the wholesale price.

10/ American Institute of Planners and Motor Vehicle Manufacturers Association of the U.S. Inc., "Urban Transportation Fact Book, Part 2, Washington, D.C. 1974.

10a/ Blake, John, "How Londoners Travel to Work," Surveyor, July 26, 1974.

between density and transit travel can be seen in Figure 1 which is based on a 1965 National Travel Survey in Great Britain. However, in support of the previous comment regarding the extensive use of the private automobile, despite high user costs, it is interesting to note the trend in London from 1966 to 1971. Between these two years the rate of increase in the use of the car for the journey to work was as high in Inner London as it was in Outer London, despite the rise in congestion in the more dense Inner London area.11/

In general, however, the economic and social benefits of living in a city--better choice of goods and services, cultural attractions, etc.--are being offset by the high cost of living in cities. Freedom of personal movement is one of these costs. This realization has resulted, at least in part, in the U.S. following the European experience in an effort to improve existing transportation systems with less emphasis on extending systems geographically. Most medium to large U.S. cities now have about as many high-type freeways in them as they can accommodate and the very large cities already have or are building fixed rail facilities. With the growing congestion in cities and increases in energy constraints, more emphasis is being placed on improved management of existing systems. This includes,

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11/ Blake, John, "How Londoners Travel to Work," Surveyor, July 26, 1974, pp. 34-35.

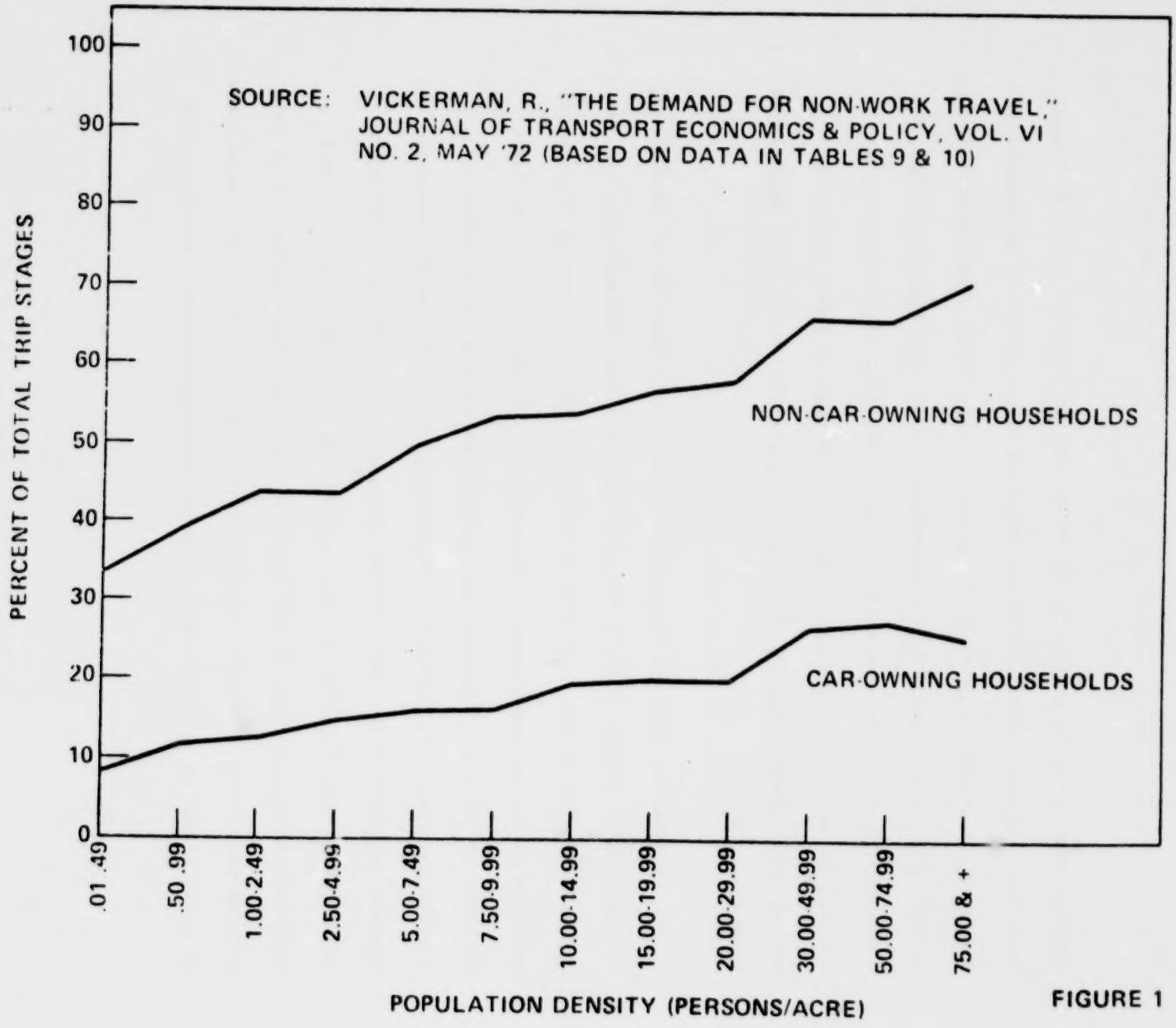
SOURCE: VICKERMAN, R., "THE DEMAND FOR NON-WORK TRAVEL," JOURNAL OF TRANSPORT ECONOMICS & POLICY, VOL. VI NO. 2, MAY '72 (BASED ON DATA IN TABLES 9 & 10)
PERCENT OF TOTAL TRIP STAGES
100
90
80
70
60
50
40
30
20
10
0
NON-CAR-OWNING HOUSEHOLDS
CAR-OWNING HOUSEHOLDS
.01 .49
.50 .99
1.00-2.49
2.50-4.99
5.00-7.49
7.50-9.99
10.00-14.99
15.00-19.99
20.00-29.99
30.00 49.99
50.00-74.99
75.00 & +
POPULATION DENSITY (PERSONS/ACRE)

FIGURE 1

carpooling, exclusive bus lanes, improved transit marketing, and improvements in traffic operation. In this respect the U.S. has an opportunity to learn from the track record of European transit systems and marketing.*

In addition, our society will always include those persons who do not own or drive cars because they are too young or old, or are handicapped and who will require another means of transport other than the private automobile. Paaswell estimates that about half the U.S. population and more than 60% of the United Kingdom population is without access to a car.12/ This segment of the population includes persons with no cars and persons in households with cars, but do not drive. In West Germany it is over 70% of the population.13/ This includes persons under 18 years, persons over 18 with no license and persons with a license, but no available car. The "carless" segment of the population must be added to the growing repertoire of transportation problems on both sides of the Atlantic.

Auto Ownership

While it is pretty certain that the automobile will be here to stay for the forseeable future and in much its present size and shape, it is not quite as clear what to expect in the way of ownership levels and usage. While urban problems have been compounded by increases in auto

Reproduced from best available copy.

* An entire issue of "Mass Transit" is devoted to current activity in international transportation problems: "Mass Transit," September 1974.

12/ Paaswell, Robert E., "Problems of the Carless in the United Kingdom and the United States," Transportation, Vol. 2, No. 4, December 1973, pp. 351-371.

13/ Schulz-Heising, J., "Carless People" Paper Commissioned by O.E.C.D., Environmental Directorate, Institut für Angewandte Sozialwissenschaften Bonn-Bad Godesberg, November 1972.

ownership, this same increase has been closely associated with economic growth. In general auto ownership at a macro level has been a manifestation of the standard of living as shown in Figure 2. It is interesting to note the shape of the U.S. curve relative to the curves for the Netherlands and West Germany implying that auto ownership may be nearing saturation levels. The Deutsches Institut für Wirtschaftsforschung, Berlin has shown that, while the growth rate for the U.S. has remained relatively stable since 1953, car ownership has continued to rise. (See Figure 2a) Increase in travel can also be related to increases in economic levels as in Figure 3.* On an international scale this relationship is seen in Figure 4 for nine nations for which 1970 data were available. The link between economy and travel can be seen.

At a more micro level there is a close relationship between a family income and its level of car ownership and travel. Figures 5, 6 and 7 illustrate this. Again the relationship for the U.S. has leveled off more than in the other two implying a nearing of saturation levels for car-owning households. Multi-car households, however, are still growing as seen in Figure 8.

---

*On the other hand, Owen makes the point that nations can be relatively prosperous without having high auto ownership rates.[14] He cites the example of Western European nations with gross national products of $1000 U.S. per capita or more and relatively high auto ownership rates (one car per 3 to 6 persons). At the same time Hungary, with a GNP of $1000 per capita, but limited production and importation of cars, had only one motor vehicle per 61 persons in 1970.[14]

[14] Owen, Wilfred, "Automobiles and Cities, Strategies For Developing Countries," Organization for Economic Cooperation and Development, Paris, 1973.

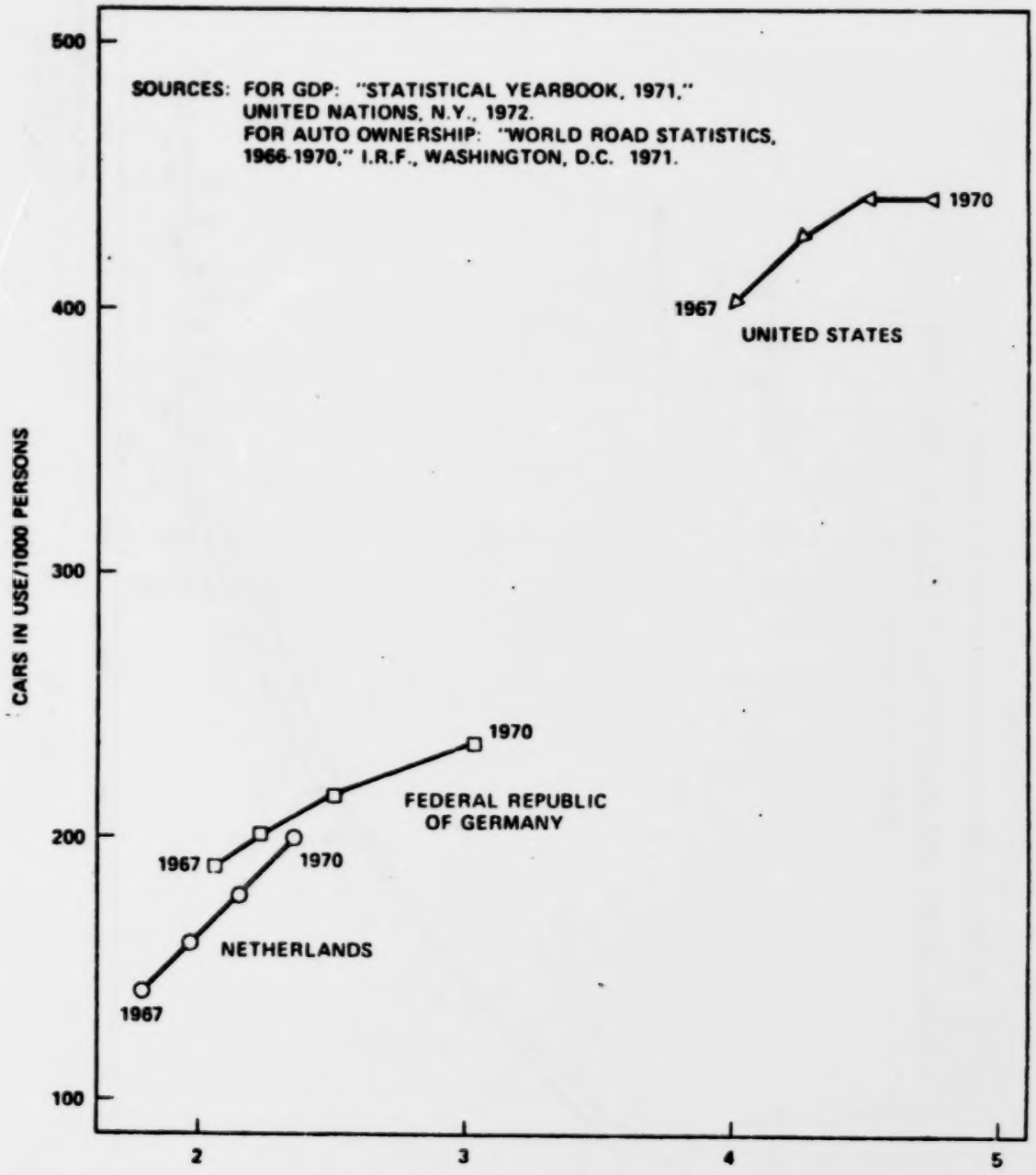
SOURCES: FOR GDP: "STATISTICAL YEARBOOK, 1971," UNITED NATIONS, N.Y., 1972.
FOR AUTO OWNERSHIP: "WORLD ROAD STATISTICS, 1966-1970," I.R.F., WASHINGTON, D.C. 1971.
500
400
300
200
100
CARS IN USE/1000 PERSONS
1970
1967
UNITED STATES
1970
FEDERAL REPUBLIC OF GERMANY
1967
1970
NETHERLANDS
1967
2
3
4
5
PER CAPITA GROSS DOMESTIC PRODUCT (000 $ U.S.) FOR 1967, '68, '69, AND '70

FIGURE 2

Automobile Density and Annual Rate of Increase

PKW-Dichte und jährliche Wachstumsraten 1953-1973
BRD, Schweden, USA

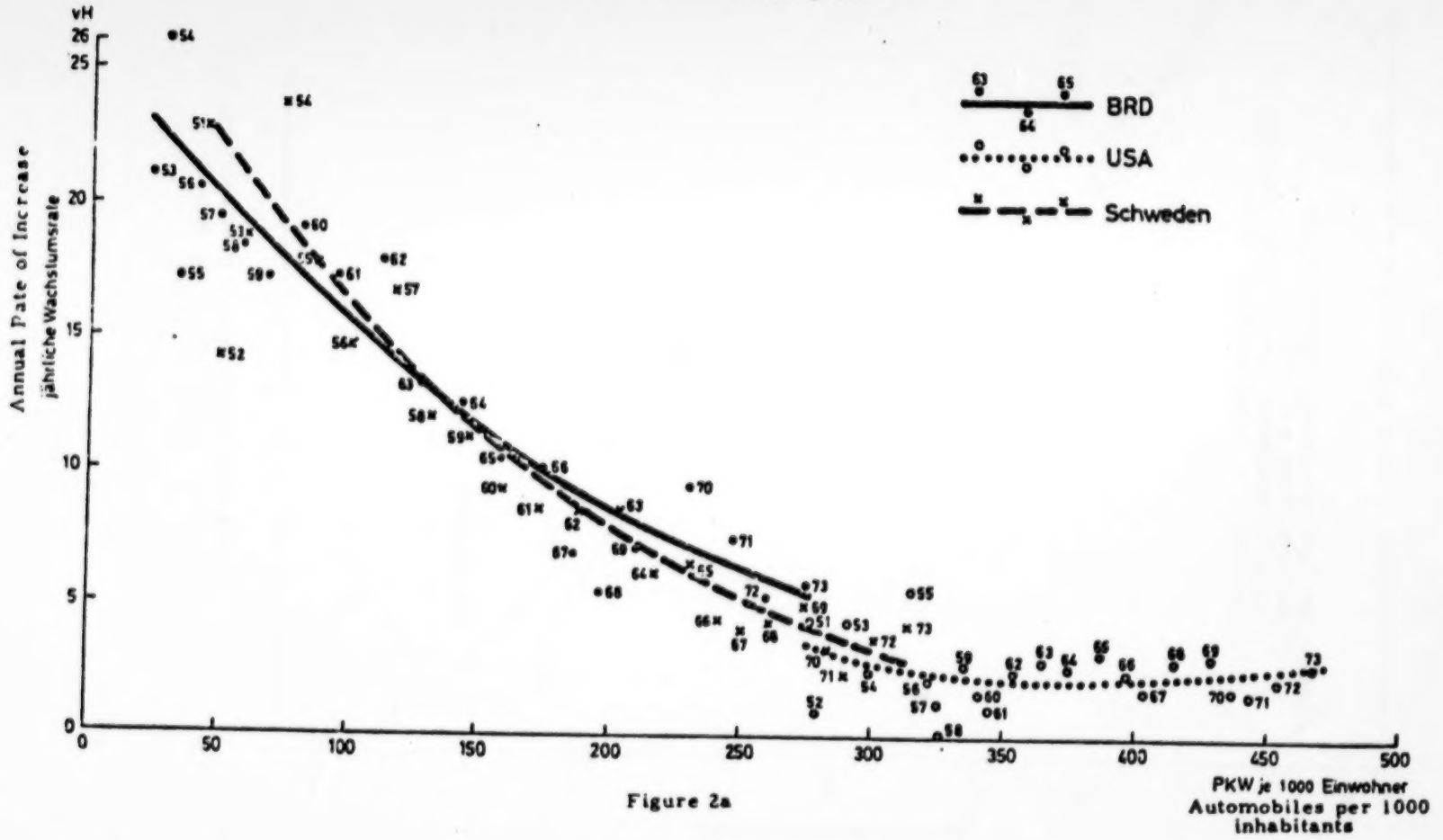

Figure 2a

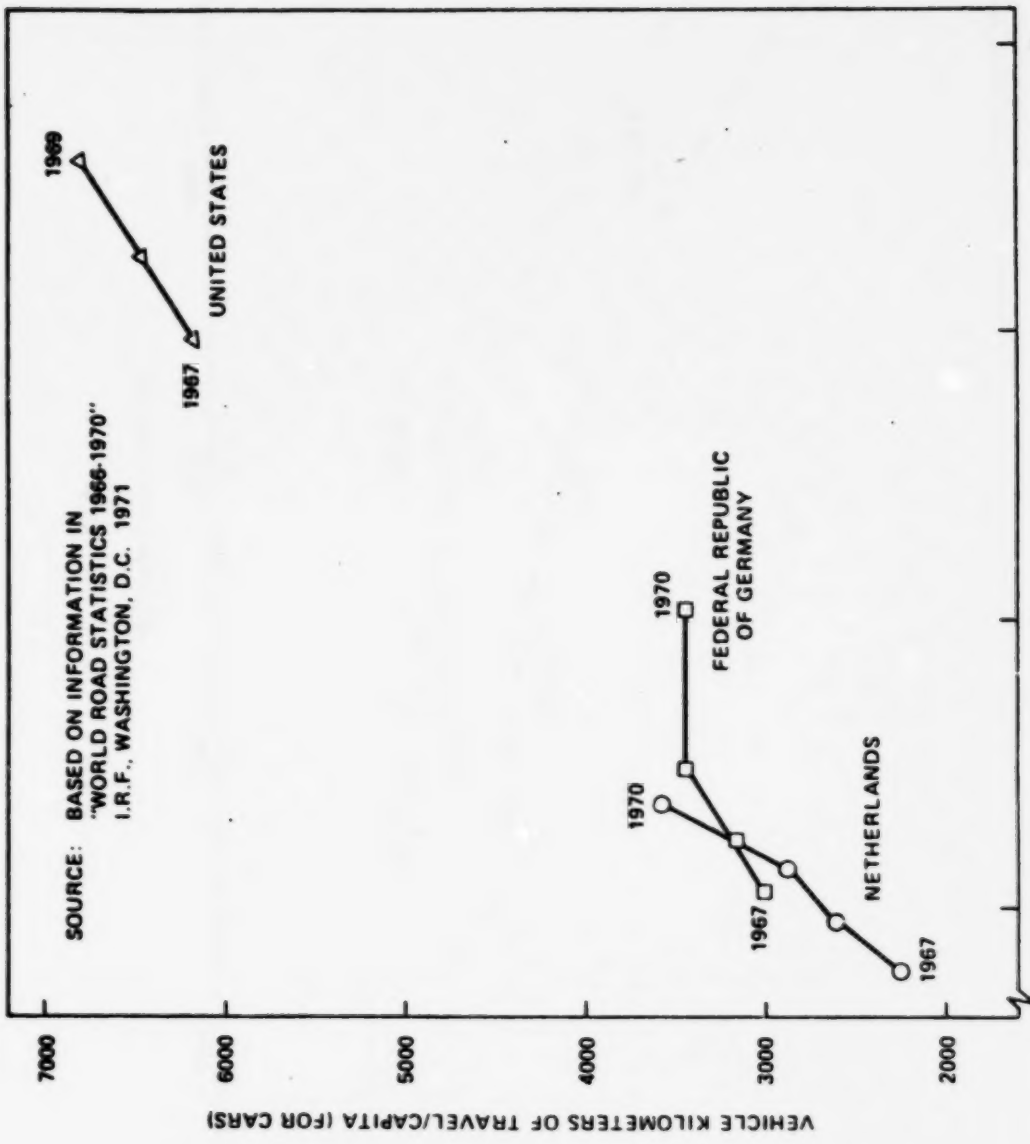
VEHICLE KILOMETERS OF TRAVEL/CAPITA (FOR CARS)
7000
6000
5000
4000
3000
2000
2
3
4
5
GROSS DOMESTIC PRODUCT PER CAPITA (000 S U.S.)
FOR 1967, '68, '69, AND '70
SOURCE: BASED ON INFORMATION IN
"WORLD ROAD STATISTICS 1966-1970"
I.R.F., WASHINGTON, D.C. 1971
1969
1967
UNITED STATES
1970
1967
FEDERAL REPUBLIC
OF GERMANY
1970
1967
NETHERLANDS

FIGURE 3

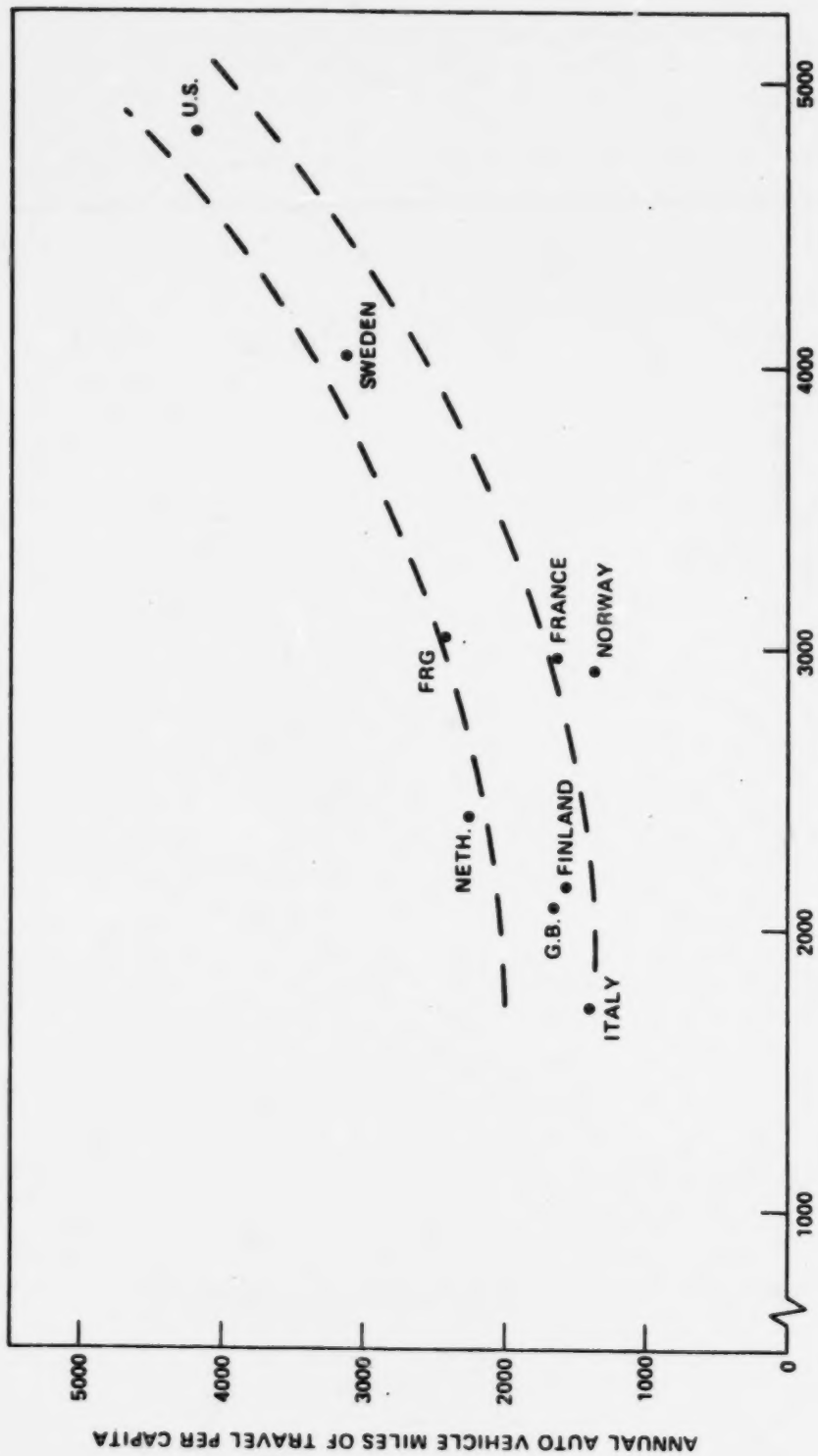
ANNUAL AUTO VEHICLE MILES OF TRAVEL PER CAPITA
5000
4000
3000
2000
1000
0
1000
2000
3000
4000
5000
1970 PER CAPITA GNP ($)
U.S.
SWEDEN
FRG
FRANCE
NORWAY
NETH.
FINLAND
G.B.
ITALY

FIGURE 4

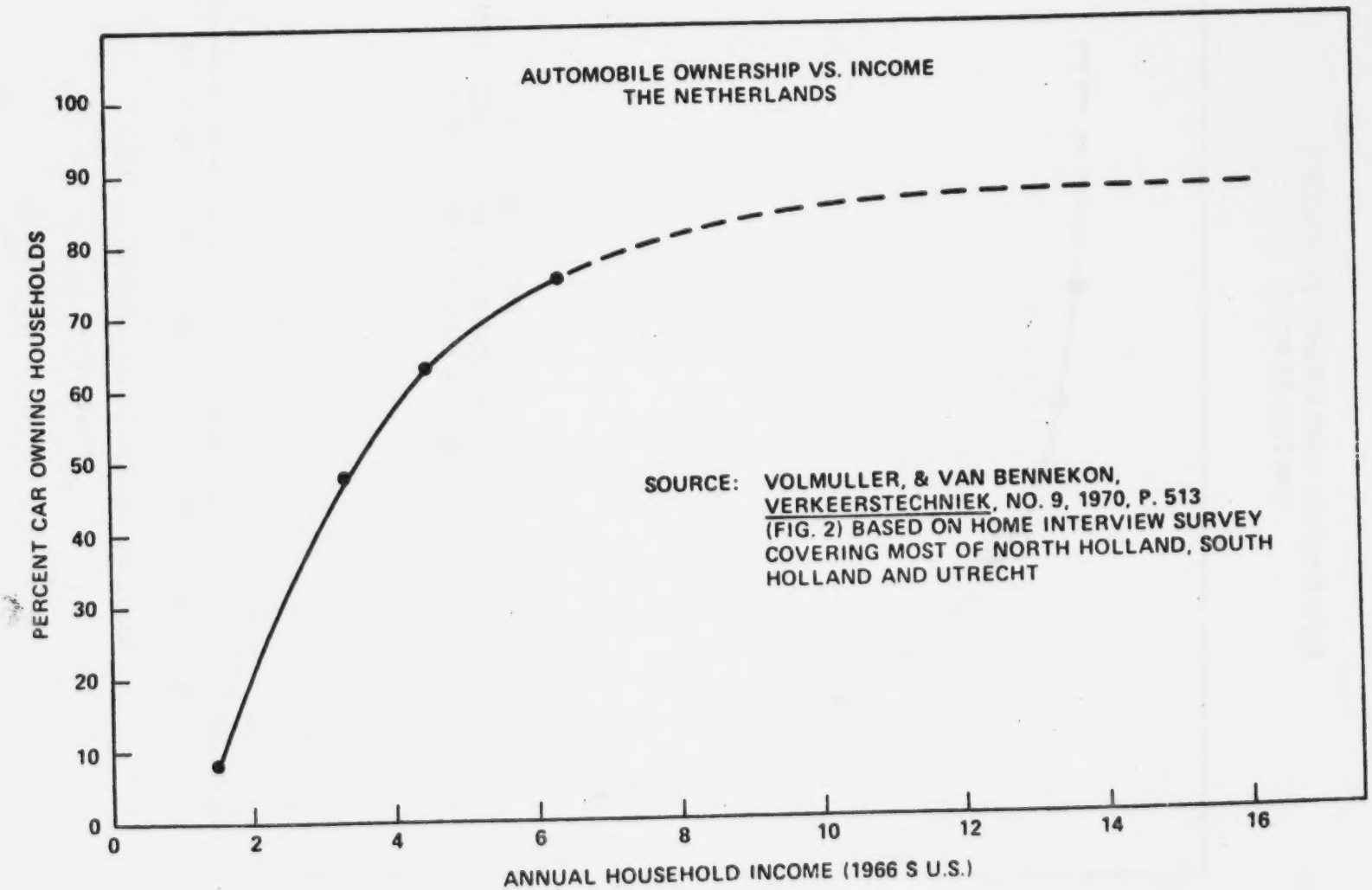
AUTOMOBILE OWNERSHIP VS. INCOME
THE NETHERLANDS
PERCENT CAR OWNING HOUSEHOLDS
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
ANNUAL HOUSEHOLD INCOME (1966 $ U.S.)
SOURCE: VOLMULLER, & VAN BENNEKON,
VERKEERSTECHNIEK, NO. 9, 1970, P. 513
(FIG. 2) BASED ON HOME INTERVIEW SURVEY
COVERING MOST OF NORTH HOLLAND, SOUTH
HOLLAND AND UTRECHT

FIGURE 5

AUTOMOBILE OWNERSHIP VS. INCOME
UNITED STATES

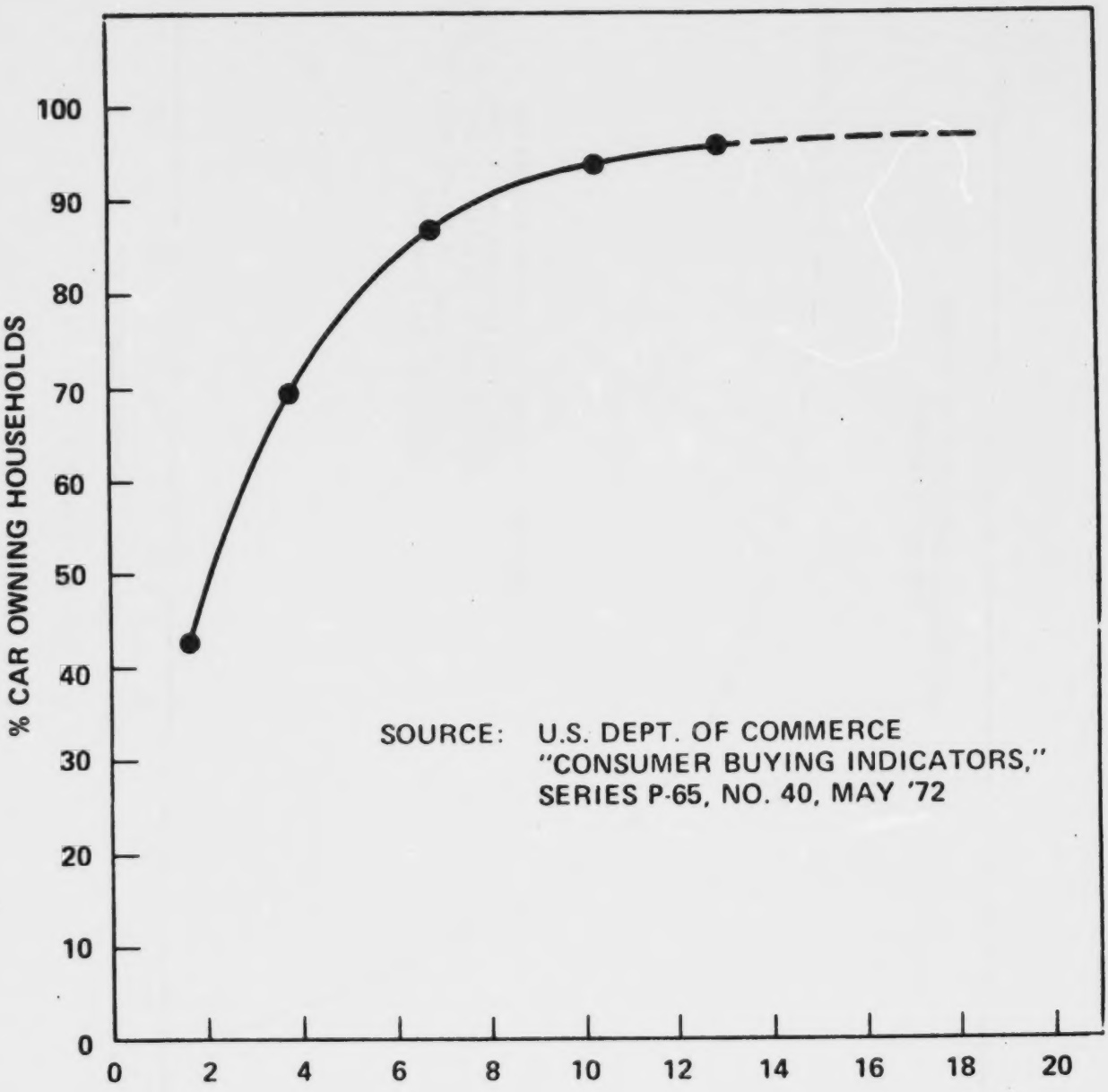

FIGURE 6

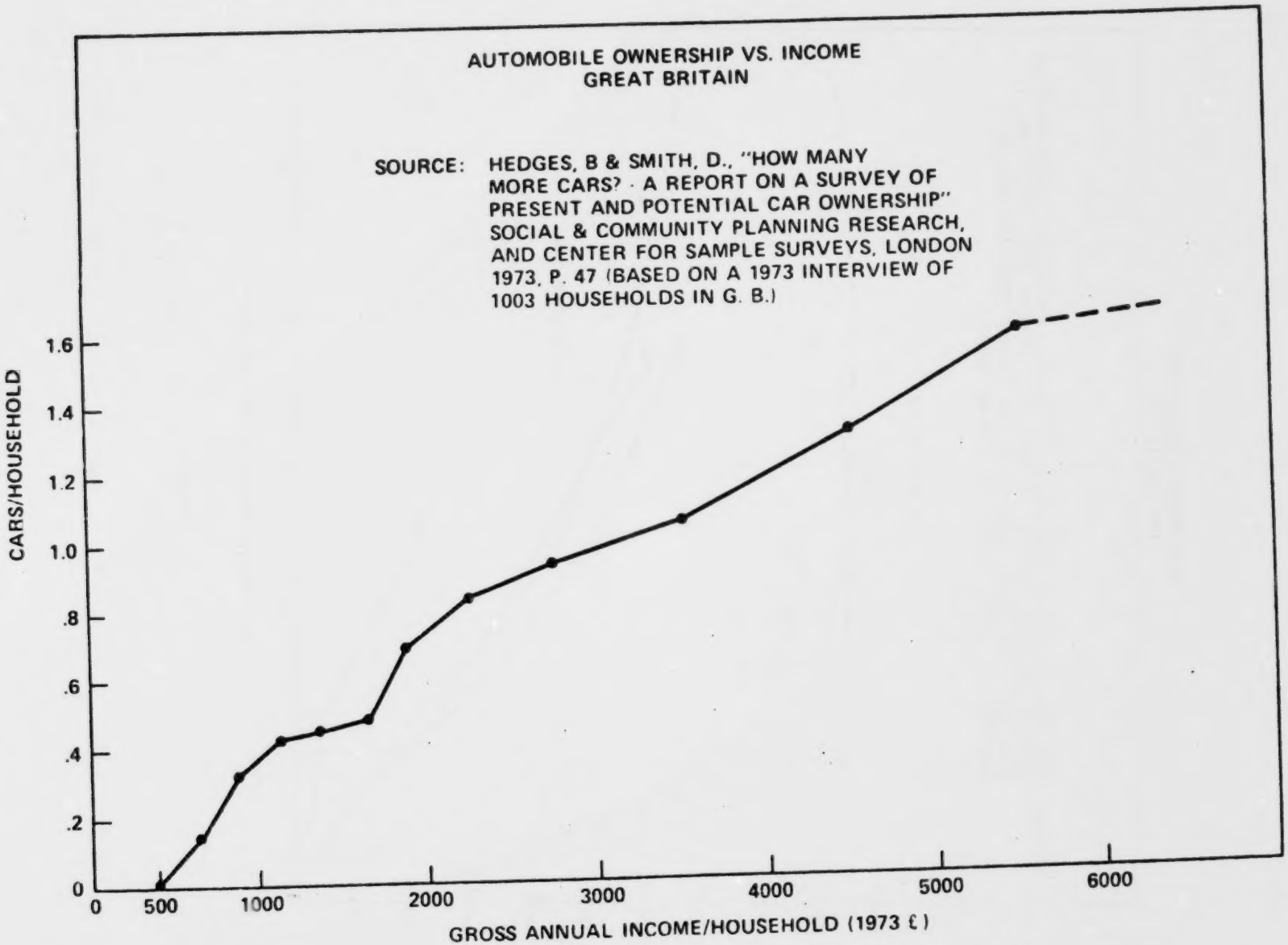
AUTOMOBILE OWNERSHIP VS. INCOME
GREAT BRITAIN
SOURCE: HEDGES, B & SMITH, D., "HOW MANY MORE CARS? - A REPORT ON A SURVEY OF PRESENT AND POTENTIAL CAR OWNERSHIP" SOCIAL & COMMUNITY PLANNING RESEARCH, AND CENTER FOR SAMPLE SURVEYS, LONDON 1973, P. 47 (BASED ON A 1973 INTERVIEW OF 1003 HOUSEHOLDS IN G. B.)
CARS/HOUSEHOLD
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
0
500
1000
2000
3000
4000
5000
6000
GROSS ANNUAL INCOME/HOUSEHOLD (1973 £)

FIGURE 7

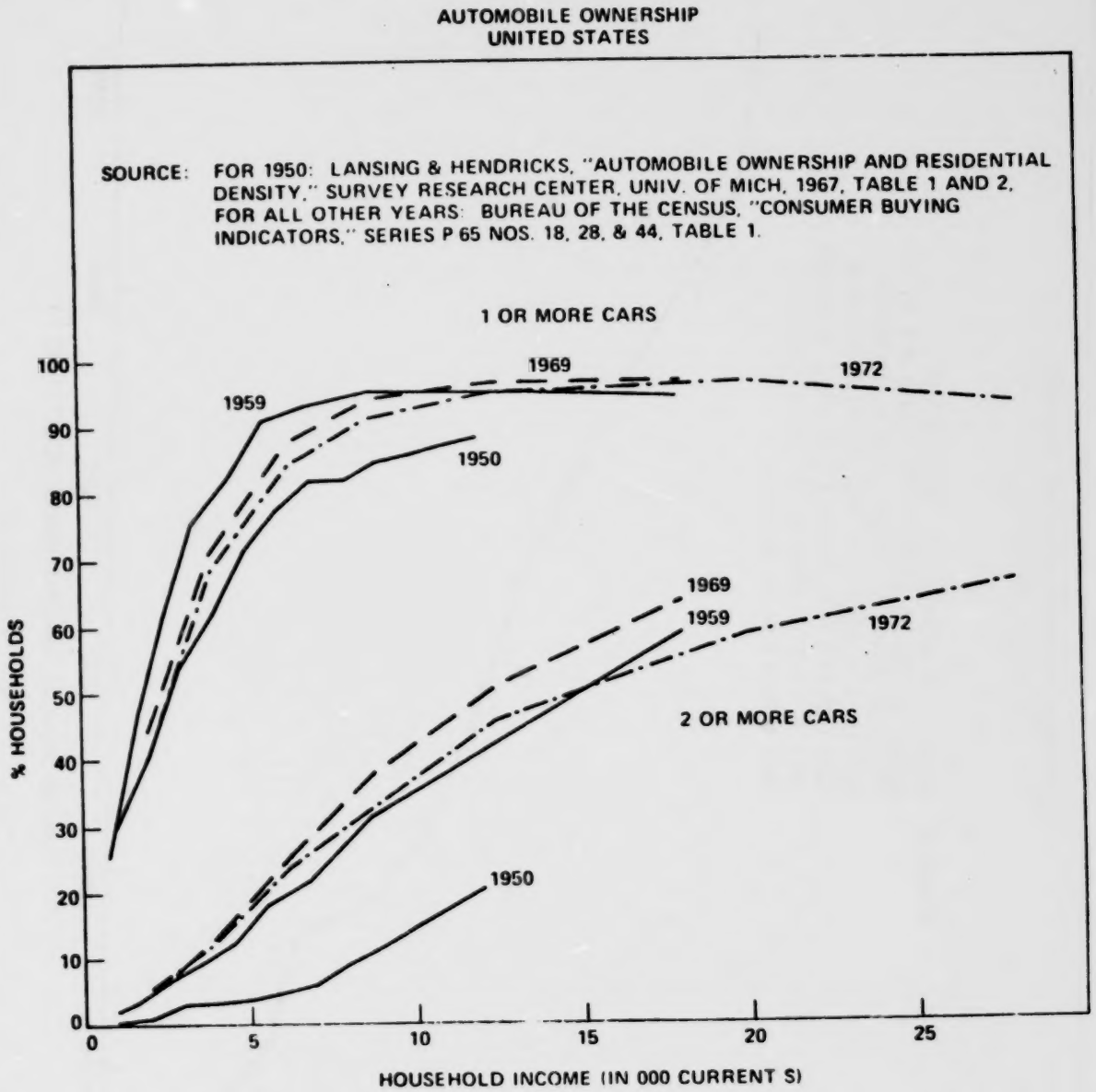
AUTOMOBILE OWNERSHIP
UNITED STATES
SOURCE: FOR 1950: LANSING & HENDRICKS, "AUTOMOBILE OWNERSHIP AND RESIDENTIAL DENSITY," SURVEY RESEARCH CENTER, UNIV. OF MICH, 1967, TABLE 1 AND 2. FOR ALL OTHER YEARS: BUREAU OF THE CENSUS, "CONSUMER BUYING INDICATORS," SERIES P 65 NOS. 18, 28, & 44, TABLE 1.
1 OR MORE CARS
1969
1972
1959
1950
2 OR MORE CARS
1969
1959
1972
1950
% HOUSEHOLDS
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
HOUSEHOLD INCOME (IN 000 CURRENT $)

FIGURE 8

In these illustrations the relative position of the various countries in terms of the economic/travel interrelationship is seen as an indication for the need to assess alternative courses of action. European countries have limited the use of private autos through such things as taxing, pricing and land use policies discussed earlier. The U.S. is now facing a similar situation regarding policies for the limitation of travel. At the same time the use of the private automobile is growing in European nations and particularly in urban regions. Under these circumstances the experiences of nations on both sides of the Atlantic can be beneficial in examining alternative courses of action.

OBJECTIVES OF THE SUBPROJECT

Because of the many and rapid changes in urban growth and travel taking place today, decision-makers are interested in the effects of alternative policies relating to variations in auto use with changing economic levels. The objective of this project was to provide guides for public officials in developing estimates of future travel likely to materialize if existing trends were allowed to continue. Because of the differing views taken toward the automobile and its relationship to urban development by Europe and the U.S., it is advantageous to draw on the experiences of each as analogies of what might happen under existing trends. Specifically, the goal was to provide a simpler, less costly, generalized urban travel forecasting procedure to provide quick information on the future growth patterns of urban travel.

In a somewhat broader sense, there were several aspects of the subproject which were intended to provide some enhancement to the state-of-the-art of travel forecasting. These were: (1) An exchange of knowledge and data on trip generation characteristics under varying social, economic, and demographic conditions; (2) investigation of the possible commonality of trip generation relationships on an international scale; (3) extend the knowledge of household trip generation analysis using cross-classification or category analysis and thereby enhance its use as a simpler, less costly forecasting tool. While the use of existing data and information was not an objective, it was a premise on which the CCMS project

was based. Thus, existing data sets from home interview surveys in several cities in each of the participating nations were utilized in this study.

Trip Generation Today

The traditional urban travel demand forecasting process has evolved into a sophisticated and relatively complex set of travel models. Multiple regression techniques involving a high degree of computational sophistication and considerable expense have been most often employed to develop the trip generation forecasts that serve as the basis for the urban transportation planning process. Also, techniques have most often been oriented to a certain geographic level of aggregation (e.g., traffic analysis zone).

Previous study, both in the United States and in Europe, has indicated the propriety in developing relationships at the level at which this trip is generated--the individual dwelling.[15/] In addition to being more efficient in explaining the propensity for trip making, and thus a potential for improved accuracy in forecasting, the procedure is not bound by geographic detail as zonal analysis is. A trips-per-household rate has more flexibility and universal application in transportation planning studies than an aggregate geographical trip estimation procedure. This is particularly true today when multiple travel estimates are often needed quickly on a sub-regional or corridor scale in testing alternative land use-travel configurations. In addition, household level trip generation

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15/For example see: Wooten, H.J., and Pick, G. W., "A Model for Trips Generated by Households," Journal of Transport Economics and Policy, Vol. I, No. 2, May 1967, pp. 137-153. Fleet, Christopher R. and Robertson, S.R. "Trip Generation in the Transportation Planning Process," Highway Research Record No. 240, Highway Research Board, Washington, D. C., 1968, pp. 11-27. "Report on Mathematical Modeling, Charlotte-Mecklenburg Urban Area Transportation Study," North Carolina State Highway Commission, September 1972. "A Simplified Approach to Trip Generation Analysis," Federal Highway Administration, Washington, D. C. (In draft, to be published summer 1975).

relationships are more efficient in monitoring the effects of changes in land activity on trip generation and the resulting impact on the surrounding transportation system. Most often it is not a zonal average that is desired, but an estimate of trips for a specific land use activity in a corner of the zone.

The benefits of utilizing a categorical rate approach (cross-classification analysis) have also been demonstrated in previous studies.16/ Among these benefits are the straight-forward nature and ease with which the relationships can be developed and applied. While it is simple in approach, it provides the analyst with a relatively clear picture of the characteristics of household tripmaking, showing clearly the causal relationships between independent and dependent variables. Further description of the technique is provided later in this report.

With this background and drawing on previous work by transportation studies it would seem that a specific trip generation approach could be recommended. In many cases the development of analytical procedures has been treated as a research effort in each urban area, which has contributed significantly to time and cost. It is appropriate, therefore, to draw on much of what has been learned in the past in transportation planning processes to help develop a generalized trip generation procedure that is simpler and easier to use.

16/ Wooten & Pick, Fleet & Robertson, op. cit.
Also: "A Recommended Approach to Trip Generation Analysis," Federal Highway Administration, Washington, D.C. (In draft, to be published Summer 1975.) (See also "Methods of Analysis" in the description of Phase II in this report.)

Rationale for Trip Generation

The foundation for this approach is the premise that there is a basic relationship between household income, auto ownership of the household, and the number of trips made by the household. This relationship is suggested by Figure 9.

Auto ownership is, of course, an important factor in the trip generation process and the procedure described here links the two--trip generation and auto ownership forecasting--together in an integral procedure. The availability of an automobile is known to be a significant determinant in the amount and character of travel and the choice of trip mode.

Income has been shown to be uniquely important in both trip generation and auto forecasting analysis. Examples are shown in Figures 5-7.

Examination of the above figures shows income and auto ownership to be independently important household indicators of trip making. It is these two variables acting together that is important and serves as the basis for the trip generation procedure used in this project. It is a two step process which has built into it the capability of addressing likely levels of auto ownership saturation as well as policy issues regarding restricted auto use.

Patterns of urban development influence the need and desirability of owning an auto. The increase in the number of suburban, low density auto dependent residential developments has a positive influence on auto ownership as shown in Figures 9a and 9b. The higher single car households in lower income ranges and higher multi-car owning households at all income levels is evident.

SOURCE: CURVES BASED ON SMOOTHED DATA FROM CHARLOTTE-MECKLENBURG URBAN AREA TRANSPORTATION STUDY

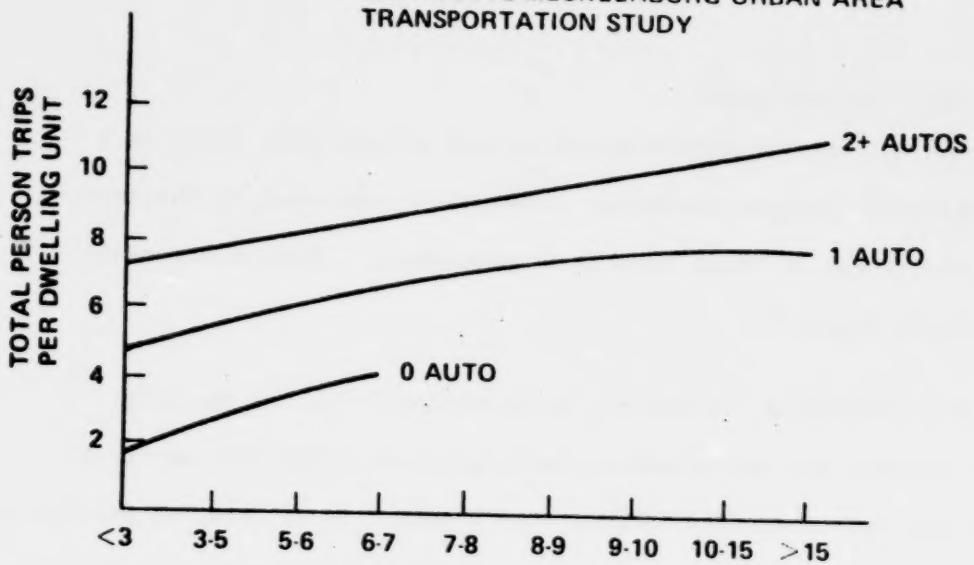
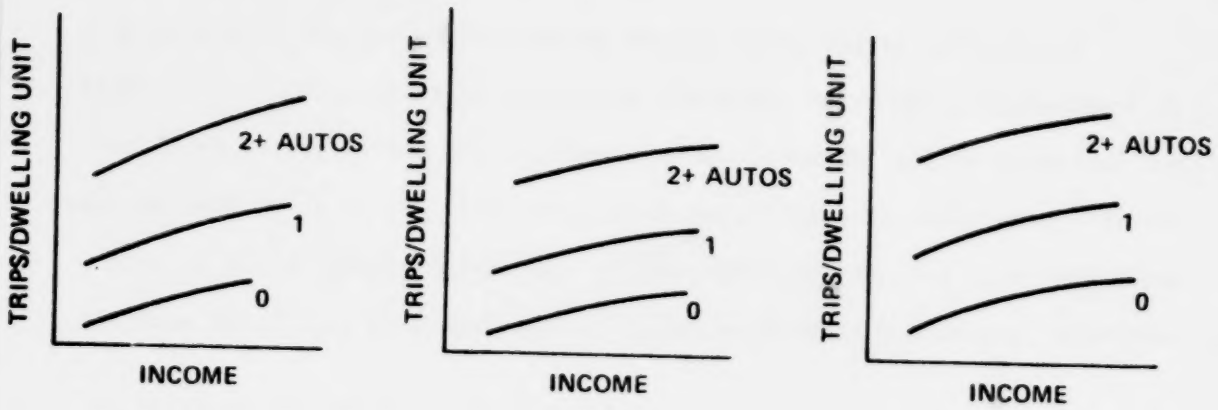
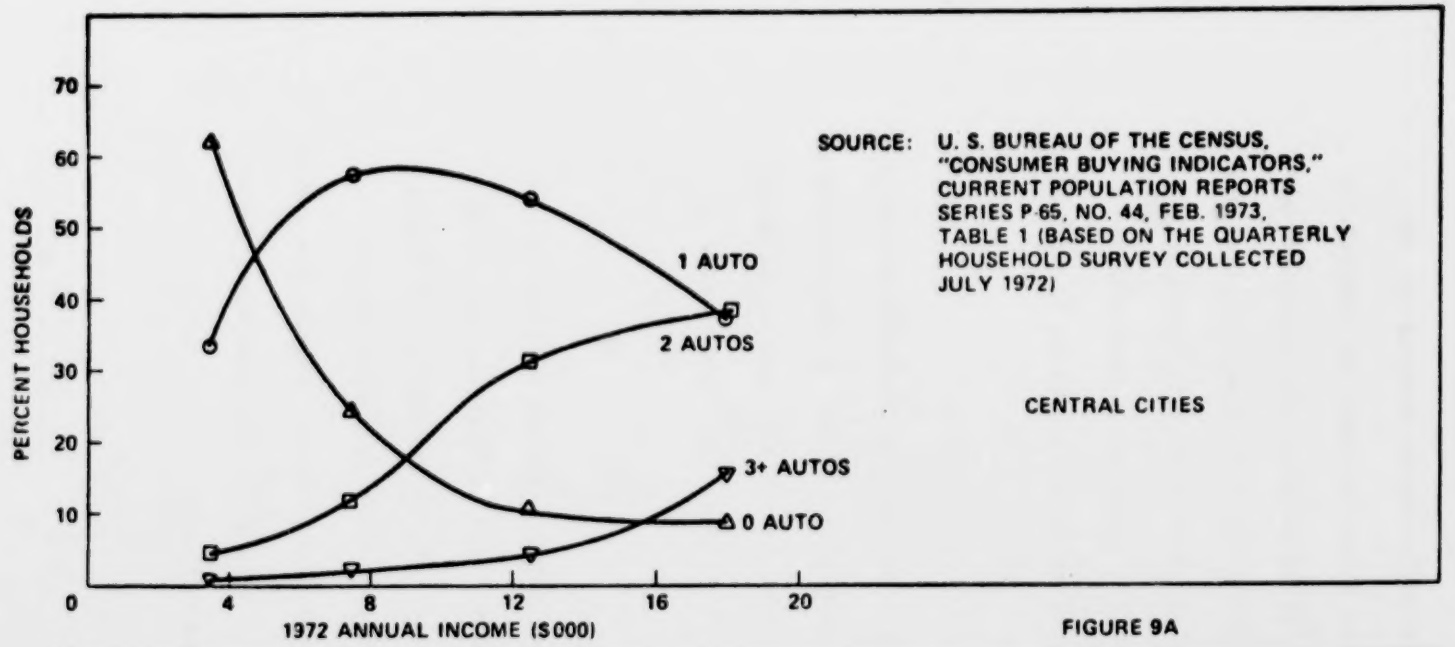


FIGURE 9



1-2 PERSONS/DU	3-4 PERSONS/DU	5+ PERSONS/DU
OR		
FAR SUBURBS	NEAR SUBURBS	INTOWN
OR		
1-4 DU/ACRE	5-10 DU/ACRE	10+ DU/ACRE

FIGURE 10



SOURCE: U. S. BUREAU OF THE CENSUS, "CONSUMER BUYING INDICATORS," CURRENT POPULATION REPORTS SERIES P-65, NO. 44, FEB. 1973, TABLE 1 (BASED ON THE QUARTERLY HOUSEHOLD SURVEY COLLECTED JULY 1972)

FIGURE 9A

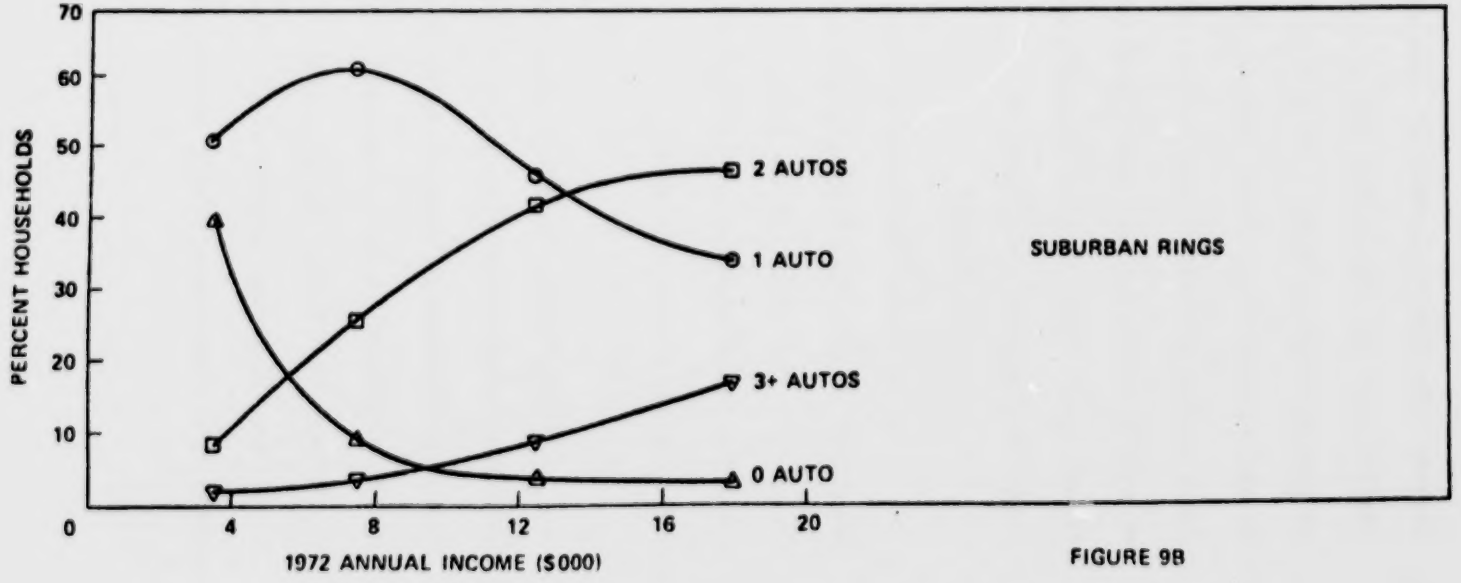
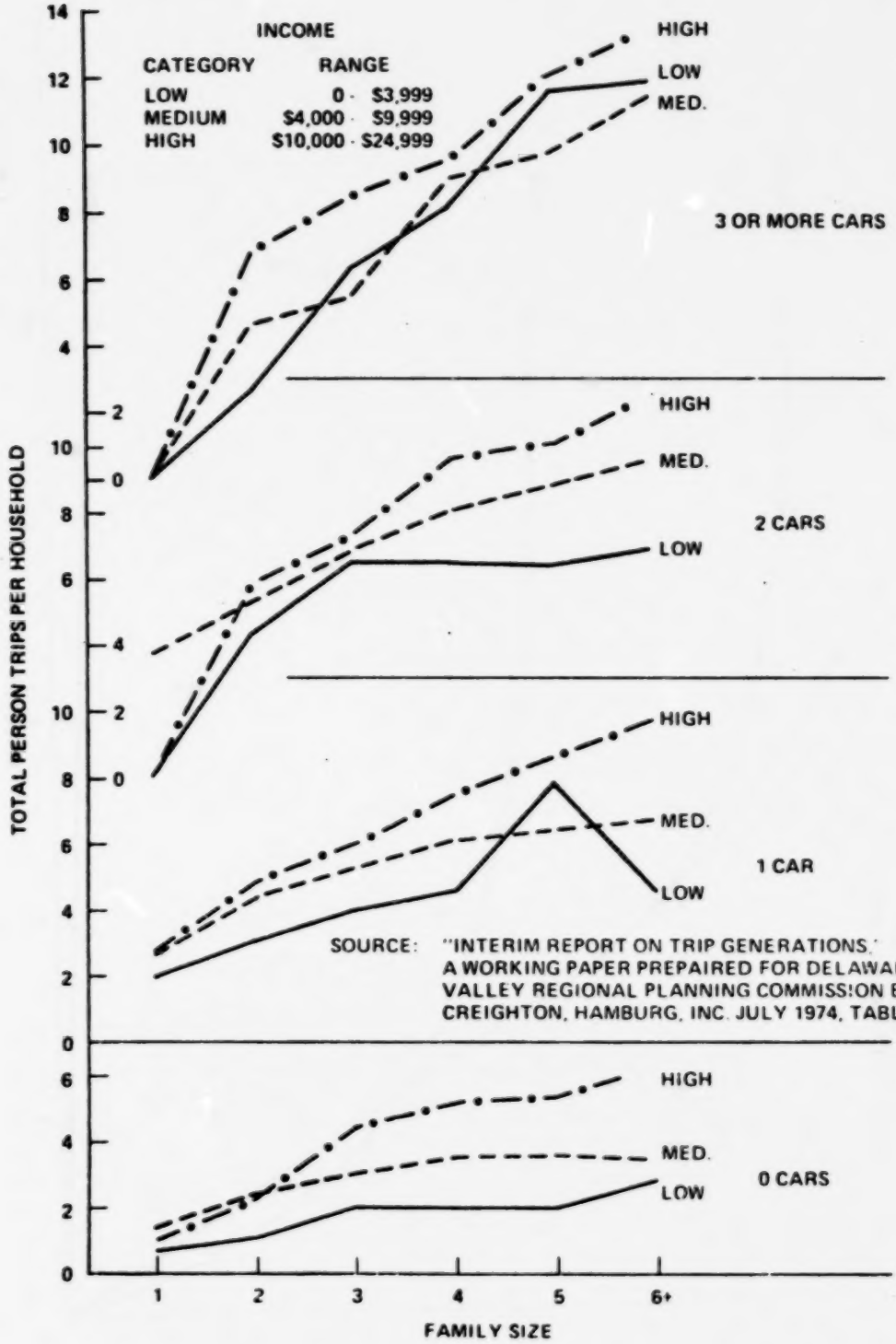


FIGURE 9B

However, the higher density of some new multi-family housing and the "filling in" of older urban and suburban areas increase the likelihood of greater transit usage. To a more limited extent, the increased use of the automobile by women and the tendency for more women to enter the labor market are additional factors which would likely increase auto ownership. And, perhaps most importantly, increases in real family income would tend to make the purchase of an initial auto or the purchase of a second more feasible.

On the other hand, recent rising environmental and social concerns mentioned earlier may have a negative impact on the use of the automobile in many of the larger urban areas and there exists the need to be able, even though perhaps rather tentatively, to access the consequences of limiting the use of the auto.

The influence of urban growth patterns mentioned earlier can be incorporated into the trip generation procedure by introducing a third independent variable such as density, size of the household, or location of the household in the urban area. Figure 10 showing hypothetical curves suggests these further stratifications of data. Figure 10a and 10b shows the effects of family size on trip making for Philadelphia, Pennsylvania, and Providence, Rhode Island, respectively.



SOURCE: "INTERIM REPORT ON TRIP GENERATIONS." A WORKING PAPER PREPAIRED FOR DELAWARE VALLEY REGIONAL PLANNING COMMISSION BY CREIGHTON, HAMBURG, INC. JULY 1974, TABLE 15.

FIGURE 10A

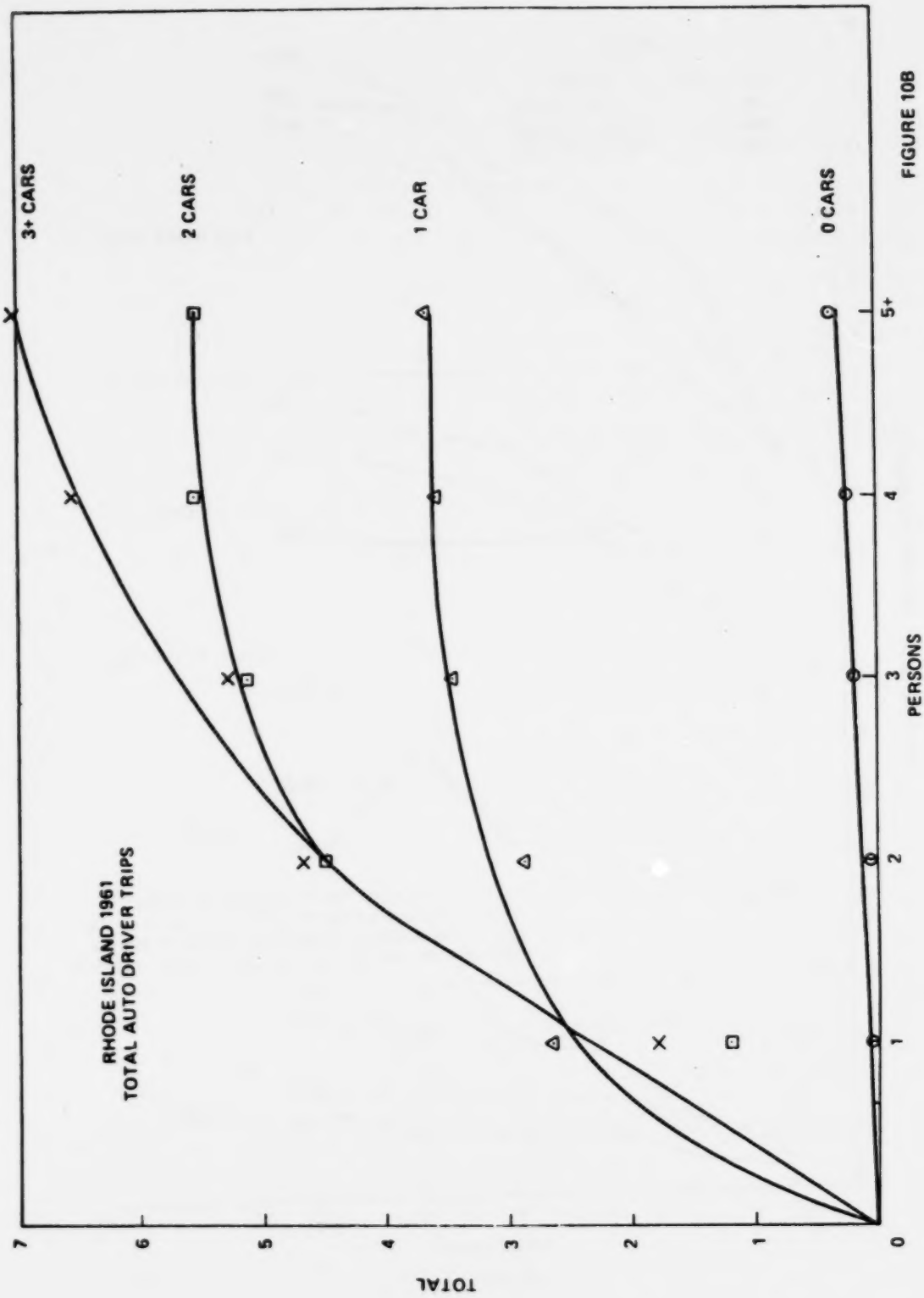

RHODE ISLAND 1961
TOTAL AUTO DRIVER TRIPS
3+ CARS
2 CARS
1 CAR
0 CARS
TOTAL
PERSONS
0
1
2
3
4
5+
7
6
5
4
3
2
1

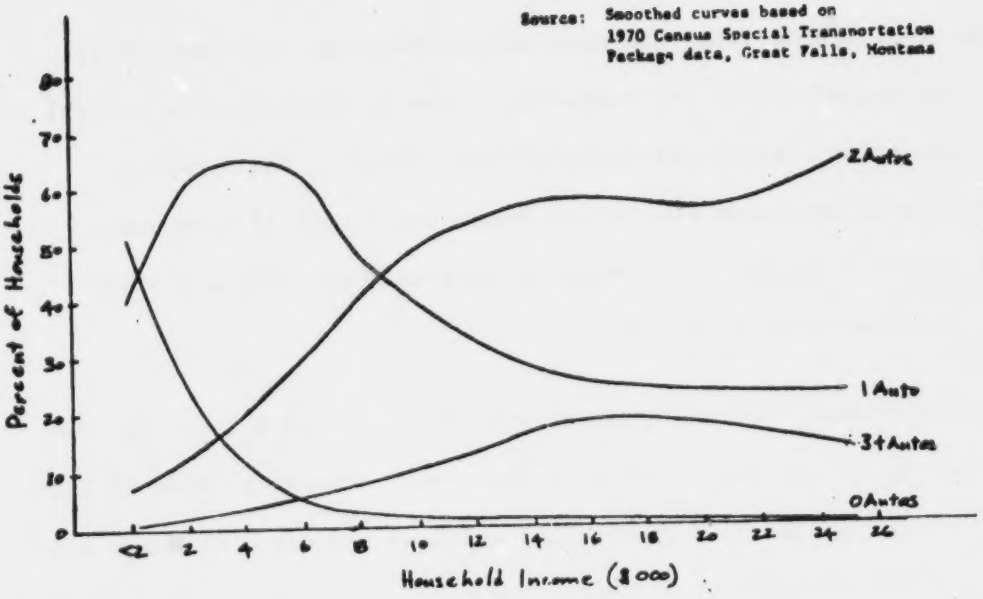
FIGURE 10B

As mentioned earlier, the auto ownership-income relationship is an important ingredient in the procedure. This is suggested for several reasons, the primary being the built-in sensitivity of the modeling approach to auto ownership saturation levels and levels of auto use. Plots of household income-auto ownership distributions show a characteristic shape as shown in Figure 11.

It is evident that there are slight shifts in the curves, but the basic structure of the distribution is the same. This gives rise, at least in part, to the thought of a generalized modeling process. With the addition of a third independent variable (density or, perhaps level of transit availability) much of this shift is likely to be accounted for. The effect of family size on auto ownership levels is shown in Figure 11a.

The relationships shown in Figure 11 are applied to determine likely levels of auto ownership, given estimated income levels. For example, given an estimated income level for a zone or other geographic area or land use type, and the total dwellings in that area, the income-auto ownership relationship can be applied to determine the number of households by auto ownership category. If a third independent variable is used (e.g., density or family size) a set of curves as in Figure 11 would be entered for each density class (e.g. low, medium, high) or family size grouping used.

With the number of households owning 0, 1, 2, or 3 or more autos known, the trips for the geographic area or land use activity can be


Source: Smoothed curves based on
1970 Census Special Transportation
Package data, Great Falls, Montana
Percent of Households
2 Autos
1 Auto
3+ Autos
0 Autos
Household Income ($000)

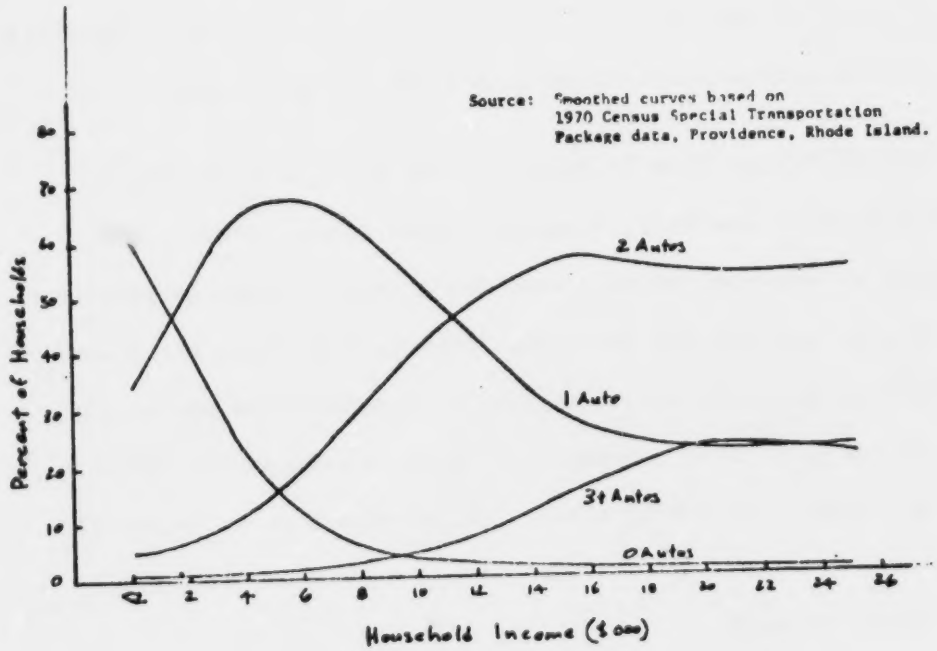
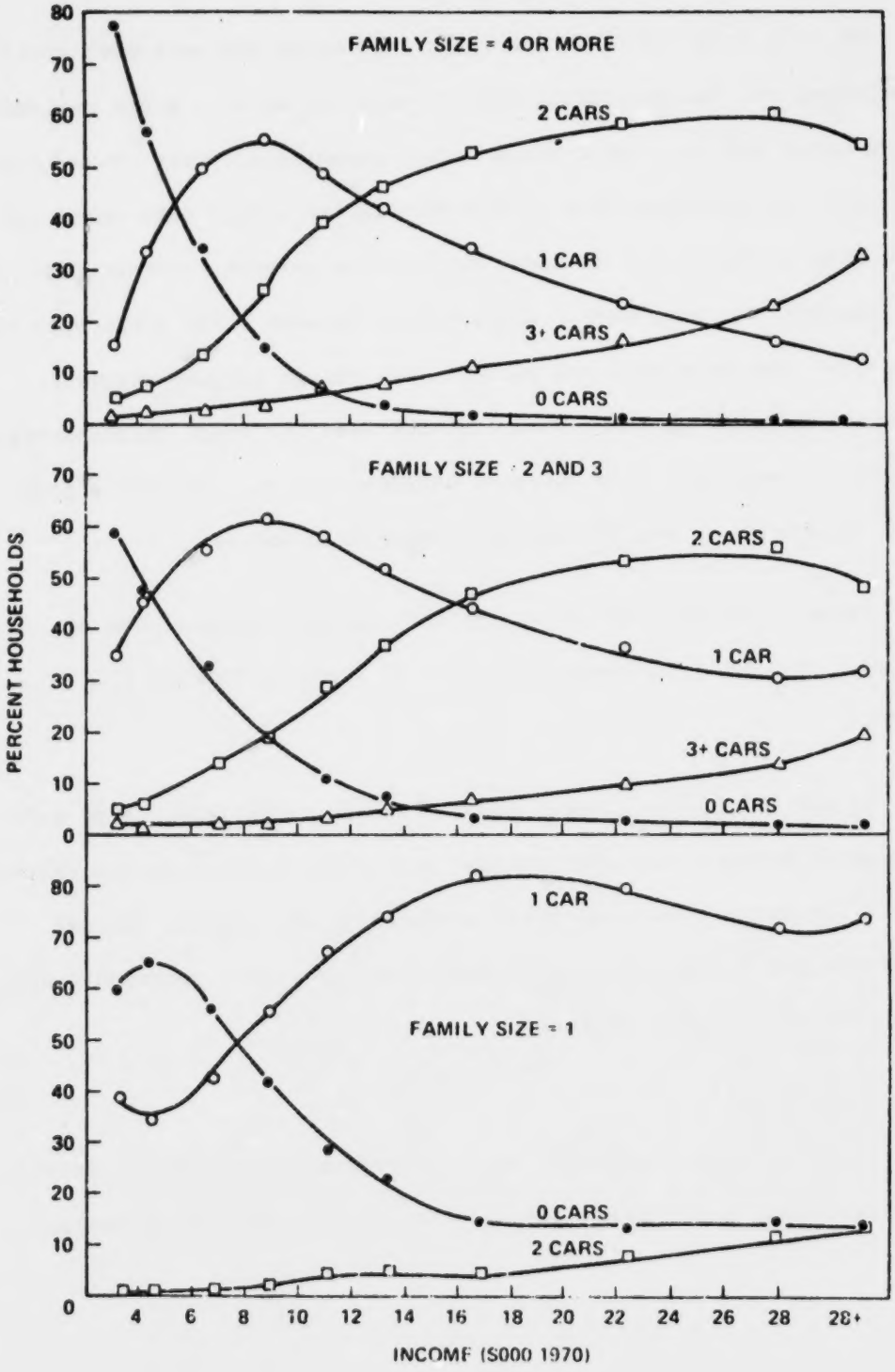

Source: Smoothed curves based on
1970 Census Special Transportation
Package data, Providence, Rhode Island.
Percent of Households
2 Autos
1 Auto
3+ Autos
0 Autos
Household Income ($000)

FIGURE 11

WASHINGTON, D.C
1968

FIGURE 11A



derived from relationships similar to those in Figure 9 or 10.

At this point total person trips (all modes and purposes) would be estimated for the geographic area in question or as a gross estimate for the urban region. For transportation planning purposes these relationships could be developed from origin-destination survey data collected in the area or they could be based on previous surveys in other regions. Investigation has shown marked similarities between urban areas when the income-auto ownership data are plotted (see Figure 11) and synthetic curves are a viable option. Data that are used for these relationships are normally available from national censuses and this is also a good source to develop or verify previously developed models.

Trips by purpose and by public and private transport can be determined through relationships similar to those in Figures 12 and 13.

In the trip purpose model non-home based trips (i.e. trips made by household members, but with neither end at the household) are estimated and used for control on total trips produced in the region. Actual productions and attractions are allocated to the proper geographic area through the trip attraction model.

The trip production modal split procedure is intended to provide general guidance as to likely levels of transit travel, given varying

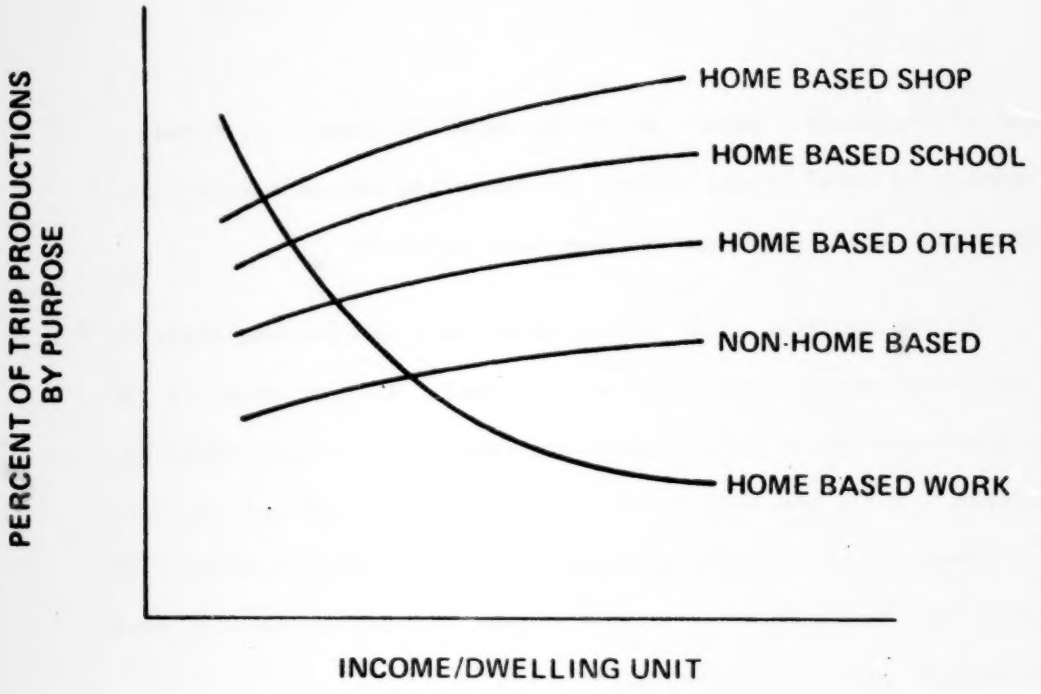


FIGURE 12

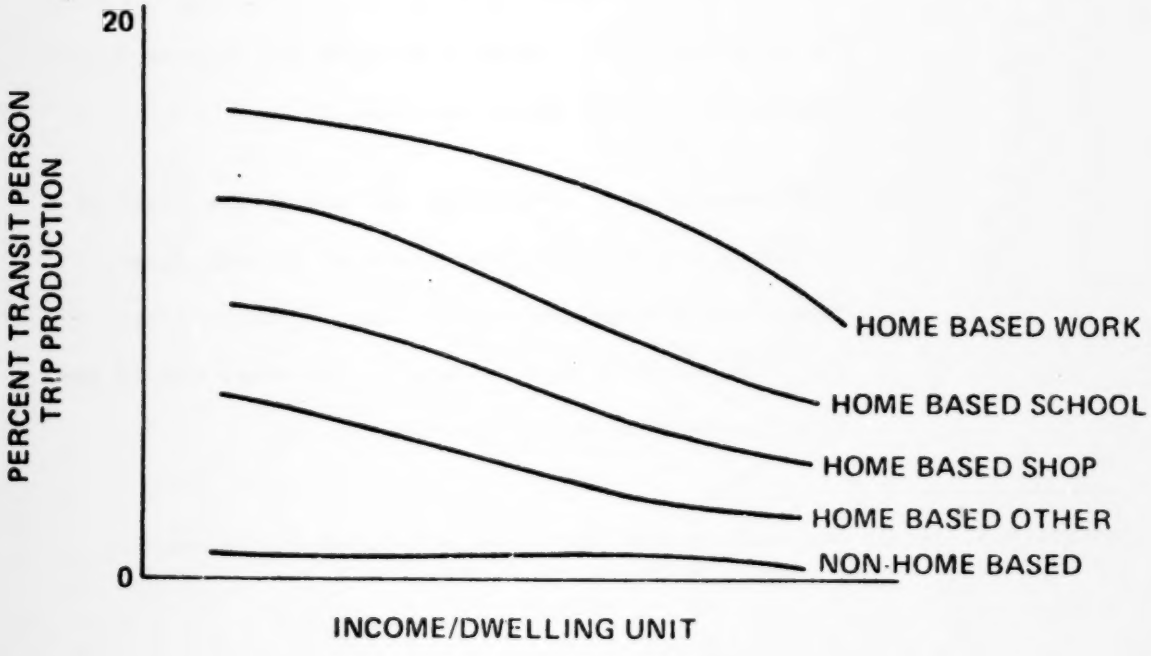


FIGURE 13

levels of household income. It is not meant to compete with more sophisticated modal choice models incorporating system variables and utility theory of travel choice (see next section).

It was apparent early in the study that limitations might be felt on the relationships that could be developed. In that event it was felt that alternative trip purpose and modal split models could be developed. These are shown in Figure 14. Figures 14b and 14c have the advantage of identifying modes other than public transit. The bicycle mode is important in most European cities and the U.S. could draw heavily on this experience.

Definitions -- The following are definitions used in this study:*

(1) Trip -- A one way weekday journey by a person made for a particular purpose (e.g. to go shopping, to school or to go to work). Usually trips by all persons 3 to 6 years of age and older are counted.

(2) Trip production -- Trips with one end at the place of residence are assumed to be produced at home (home based trip productions) regardless of the direction of the trip (i.e. to or from home). The other end of the trip is the trip attraction end.

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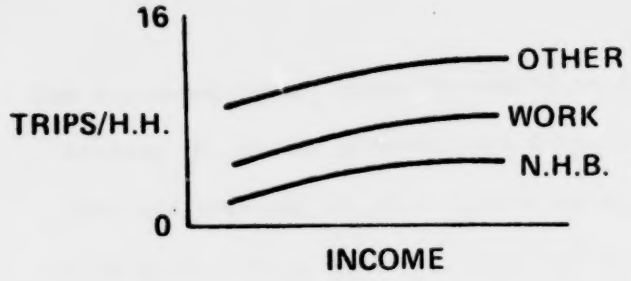
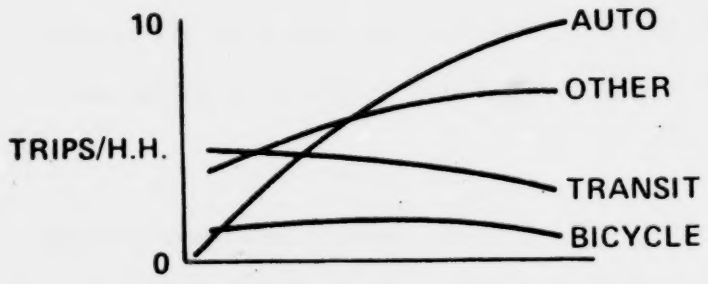
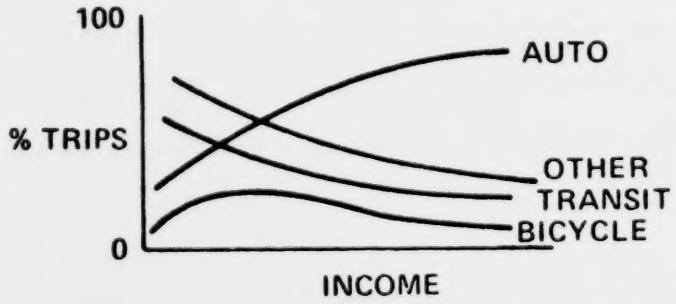
*Additional detail and information specifically related to the data sources used in this study is contained in Appendix A.



14A



14B



14C

FIGURE 14

(3) Linked Trips -- Stages of trips (serve passenger and change travel mode) are commonly linked, by certain criteria, into an overall trip to preserve the real reason to make the trip. In most cases linked trips were used in this study; but, in some cases serve passenger and change travel mode trips were treated separately.

(4) Household Income -- Gross annual income by all members of the household. For further comment on income see next section.

(5) Auto Ownership -- All autos owned or available for use (includes company cars) by members of the family.

(6) Household -- This varied somewhat between countries but generally comprised a person living alone, a group of unrelated persons living together and sharing housekeeping, or a family.

(7) Family Size -- Total persons living in the household including members temporarily absent on the day of the interview. Generally includes relatives living in the household.

(8) Mode -- Means by which the trip is made (e.g. auto, transit, bicycle, walk, etc.).

Income Adjustment -- In an attempt to provide consistency between data sets and aid in evaluating trip production relationships, all income values were converted to 1970 $U.S. before plotting. Where income (other than $U.S.) was in units for some other year the values were first converted to 1970 using annual average rates of consumer price index for the particular country,[17] and then converted to $U.S. using 1970 conversion rates.

There are other considerations concerning income that should be brought to bear on this analysis (e.g. relative disposable income, effect of differences in purchase price of a new auto-mobile, or the amount of income spent on transportation). While these were not introduced as an integral part of the models developed, they were considered as external factors in the analysis. See "Results" in the discussion of the Phase II work.

Structure of the Subproject Within the Broader Context of Travel Demand Forecasting

A considerable amount of research has been undertaken recently in travel demand forecasting which should lead to improvement in forecasting techniques.

Current transportation planning models usually consist of a sequential set of elements from trip generation through distribution,

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17 / United Nations, "Statistical Yearbook, 1971," New York 1972, Table 176.

modal choice and traffic assignment. The techniques have been categorized as being aggregate in nature (models are developed and applied based on data aggregated on some geographic scale) and "choice abstract" (travel choice variables are identified by their transportation system or level of service variables, such as travel cost, irrespective of their individual trip characteristics, such as time of day, mode or destination), and they are "deterministic" in that the models give a single "best" estimate of travel (total trips in an aggregate model).

Within the past few years there has been increasing interest in the area of travel demand modeling and the incorporation of all elements of travel choice prediction (i.e. trip generation, distribution and modal choice) in one process. These "direct demand" models in the future will tend to be "behavioral" in nature (describing the reaction process of an individual or group of individuals when faced with a transportation alternative). Models that are "probabilistic" in structure will be available so that the probability of selecting an alternative can be evaluated, and they will likely be "choice specific" which might assume, for example, that travel cost by auto should be evaluated differently than travel cost by rapid rail transit. In addition, the modeling process could be either "simultaneous" (in which the trip maker is assumed to decide on trip frequency, destination, mode and route simultaneously)

or "sequential" (assuming that the trip maker makes the above choices in a step-by-step process).*

In trip generation analysis, the most widespread procedure in the past has been an aggregate approach where observations about individual

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*For additional discussion and examples of current activity on an international scale in travel demand forecasting see:

(1) "Urban Travel Demand Forecasting," proceedings of a Conference Held in Williamsburg, Virginia, December 1972; Transportation Research Board Special Report 143, Washington, D.C. 1973.

(2) "Proceedings of the International Conference on Transportation Research," First Conference held at Bruges, Belgium, June 1973; Transportation Research Forum and College d'Europe, 1974.

(3) "Behavioral Demand Modeling and Valuation of Travel Time," proceedings of a Conference held July 1973 in South Berwick, Maine; Transportation Research Board Special Report 149, Washington, D.C. 1974.

(4) Seminar "Grundsatzprobleme bei Langfristprognosen im Personenverkehr" (General Problems of Long-term Forecasting in Person Transport). Berlin, September 1974. Proceedings will be published in summer 1975 by the Deutsche Verkehrswissenschaftliche Gesellschaft (German Society for Transportation Sciences).

trip making characteristics were combined, usually on a geographic basis (traffic analysis zone) and then analyzed and used to develop the model. More recently, however, a disaggregate behavioral approach to trip generation has been applied in which the individuals (or at least individual households) have been the unit of observation.

There is little question that improvements will continue to be made in travel forecasting. Much of the change is probably far enough in the future to limit serious consideration for practical application today. However, improved methods which have wider application and are easier to use and which can be implemented within the current modeling framework offer significant advantages. Disaggregate trip generation using cross classification analysis can be applied within existing methodology and provide the planner with a usable analysis tool within this framework.

Within this context the NATO/CCMS subproject is addressed to the question of trip generation and the extent to which this element in the forecasting process can be generalized. While other elements are considered important, it was initially felt that a study of trip generation was an area which potentially could offer the most progress in terms of cost and time savings. As trip generation currently forms a basis for travel forecasting, it was felt that a generalized procedure evolving from this project would have the biggest payoff in applicability to participating nations. It was also clear that an investigation of the

total travel demand estimation picture within this subproject would be beyond the scope of available time and resources of the participating nations. Based on the results of this subproject, however, a strong case could be made for exploration into other elements of the process.*

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* For example, A. J. Daly reports on work done by the Local Government Operational Research Unit (G.B.) in developing a "global" individual mode choice model applicable to a number of towns in England: "Research on Transport Demand Models," Proceedings--Fifteenth Annual Meeting, Transportation Research Forum, 1974, p. 354.

Work done in the Netherlands for the Projectbureau Integrale Verkeers-en Vervoerstudies investigated disaggregate and simultaneous behavioral travel demand models in a Dutch context. It was felt the success of the study justified further work in a number of areas, among them the transferability of the models across different geographic areas and different socio-economic groups: "Disaggregate and Simultaneous Travel Demand Models: A Dutch Case Study," a study carried out under contract to Projectbureau Integrale Verkeers-en Vervoerstudies, The Hague, Netherlands, 1974.

On a more macro scale, work has been done in the U.S. on procedures that will allow one to assess alternative mixes and levels of transportation investment to probing for an "optimum." For example see: Weiner, E., "The TRANS Urban Model System and Its Application to the 1972 National Transportation Study, "Proceedings of the International Conference on Transportation Research, Bruges, Belgium 1973; Transportation Research Forum 1974, pp. 103-118.

STUDY BACKGROUND

As initially conceived, the subproject was intended to draw directly on transportation study data to explore the possibility of of generalized trip models. Early discussion with representatives of participating nations in mid-1973 indicated a need to conduct a preliminary analysis on the data sets that might be available for the study. Such things as data consistency, differences in definition, and commonality which might effect the outcome of the study were to be examined.

Participating nations supplied the information necessary to make this analysis (Phase I of the Study completed October 1973) and results indicated that there was enough consistency to allow further investigation (Phase II).

Phase II was concerned with analyzing the home interview data sets supplied during 1974 by the participating nations. This analysis was conducted late in 1974 and has continued into 1975, with the results described in the remaining sections of this report.

THE STUDY - PHASE I

INTRODUCTION

The initial meeting of the Travel Forecasting Subproject was held at NATO Headquarters in Brussels on June 25, 1973. Initial statements were made concerning the objectives and overall scope of the Subproject. Discussion by the delegates centered on experiences and current status of transportation studies in their respective countries. Views of the proposed work statement, distributed to the participating countries prior to the meeting, were also discussed quite freely and with a good exchange of views and opinions. Several main considerations emerged from these discussions. The two major views concerned (1) comparability of data between nations and (2) the scope of the proposed project.

Major Views of Delegates Concerning the Subproject

A general reservation was expressed about the comparability of data and the possibility of obtaining a generalized travel forecasting technique. All representatives had, to varying degrees, concern over this aspect of the project. It was suggested that comparisons of basic socio-economic data should precede analysis of travel demand relationships and that correcting formulas for the basic relationships might be necessary (both ideas have been addressed in the course of this project).

The original proposal for this project was based on the premise that major differences in trip making characteristics could be defined by a basic set of independent variables. In other words, differences between

cities in terms of such things as character, density, availability of transit, age, etc. could identify the differences between the auto ownership and trip generation relationships. It was clear, however, that the potential problems of data comparability and uniformity of data definition were sufficiently real to lead to a revised proposal for a two-phase project. An analysis of the commonality of the available data from the participating nations would constitute the first phase. This work is described below.

The second major view was that the project as proposed was not sufficiently broad and did not cover the whole travel demand estimation picture. It was the general feeling among the delegates that the usefulness of the results of this project would be limited by the scope of the proposed investigation. Consideration should be given to the other phases of travel forecasting also.

The original proposal dealt only with the trip generation portion of the forecasting process, since it was felt that this was the area in which the most progress could be made in terms of both cost and time savings. As trip generation forms a basis for travel forecasting, it was felt a generalized procedure evolving from this project would have the greatest applicability to participating nations. It was also clear that an investigation of the total travel demand estimation picture within this subproject would be beyond the scope of available time and resources of the participating nations.

The participants agreed that elements of the travel forecasting process other than trip generation deserve study also and consideration should be given to further proposals in this regard among the allied delegates. Indeed, considerable research is being undertaken in the U.S. and elsewhere in such areas as behavioral travel demand estimation and the utilitarian theory of travel mode choice. It was felt, however, that the original proposal was the most appropriate effort to be undertaken at this time. The desirability of including additional analysis in any possible future extension of the subproject, based on the success of the trip generation work, should be an important consideration. See "Summary" Section of this report for further comment.

Additional Concerns

Three additional concerns evolved during the first experts' meeting relating to the proposed work program. First, the proposal recommended the use of household level category analysis as the principal means of trip generation relationship development. This was based on research and experience gained in its application both in the U.S. and Ireland.[18/] Some concern

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18/ For example: Wooten, H. J., and Pick, G.W., "A Model for Trips Generated by Households," Journal of Transport Economics and Policy, Vol. I, No. 2, May 1967. "Report on Mathematical Modeling, Charlotte-Mecklenburg Urban Area Transportation Study," North Carolina State Highway Commission, September 1972. "A Simplified Approach to Trip Generation Analysis," Federal Highway Administration, Washington, D.C. (in draft, to be published Summer 1975). "Texarkana Urban Transportation Study, The Development and Application of Trip Generation and Distribution Models, 1965-1995," Texas and Arkansas Highway Departments, October 1973. "Dublin Transportation Study, Technical Reports," An Foras Forbartha, Dublin, Ireland, August 1972.

was expressed that category analysis had not been used in at least two of the participating nations and that difficulties are often encountered in forecasting the categories of independent variables. In this regard it was felt that this approach would best carry out the objectives of the project concerned with a generalized model that is simple and less costly to employ . Also it was felt that the difficulties with forecasting were not sufficiently critical and that a forecasting capability has been demonstrated elsewhere.19/ (See discussion of this aspect in "Application of Developed Relationships.") One adjunct to the trip generation approach was that it employed independent variables which could be updated from data obtained from the national censuses conducted in the respective countries.

The second additional concern was for the applicability of the approach on a national scale. While the emphasis of this subproject is on urban travel forecasting, the procedures have been used to develop national travel estimates.20/ Relationships developed from U.S. national survey data have been included in this subproject for comparative purposes (see Phase II discussion). In addition several States in the U.S. are currently investigating category analysis for statewide trip generation

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19/ "Dublin Transportation Study, Technical Reports," An Foras Forbartha, Dublin, Ireland, August 1972. "A Simplified Approach to Trip Generation Analysis," Federal Highway Administration, Washington, D.C. (in draft, to be published in Summer 1975). "Caguas Metropolitan Area Transportation Study, Trip Generation," C.E. Maguire, Inc. and COMSIS Corporation for Commonwealth of Peurto Rico, 1974.

20/ "Highway Travel Forecasts," Federal Highway Administration, Washington, D.C., November 1974.

analysis. Other analytical efforts, such as national application, were suggested for a possible future phase of this work as an outgrowth of the first experts' meeting.

Third, it was determined that the contrast in bicycle usage between U.S. and European cities was important and, to the extent possible, this mode of travel would be included in the analysis. Characteristics of this travel mode would offer an important insight for U.S. application.

Objectives of Phase I

Because of the concern over the possible lack of commonality, or at least compatability, of data between participating nations and possible definitional problems that might prove difficult to reconcile for purposes of useful analysis, it was agreed that an initial analysis (Phase I) of readily available data would be made. This would determine the degree to which there was a common base for such items as definition, method of data collection, existing formats, etc. in the data from home interview surveys in the participating nations.

Under Phase I, each participant in the project provided to the U.S. information regarding data availability, definitions of data items, and any background information that would be useful in the conduct of Phase II.

FINDINGS OF PHASE I

The material and information received from participating countries and analyzed by the U.S. is summarized and presented in tabular form in Appendix A to this report. Each of the important data items or variables is presented in terms of definition and/or coverage. Where appropriate, additional information is given regarding method of collection, format, and additional modifying remarks. Each item is cross-stratified with each city or, in some cases, the information pertains to the entire set or parts of the set of cities for which information was supplied by the participating country. Data available ranged from cities of over 5 million population to about 60,000 population with survey years extending from 1963 through 1972. Sample sizes of the representative home interviews ranged from 1.5 percent for the largest study to 20 percent, although this was not for the smallest of the cities represented.

Commonality of Data

For the most part, it appeared that the data items requested by the U.S. to conduct Phase I were represented in the information supplied by the participating nations and the data were apparently readily available. Two exceptions were residential density and location of household. It was envisioned that these two items could probably be obtained by identification of the

zone of residence in each household record on a zone map of the transportation study area. It was anticipated at that point prior to Phase II that location would be defined by three descriptors: in-town, near suburbs, and far suburbs, and each participating country could determine ranges of zones in the study area that would fall into each category. Family size could serve as a proxy for residential density. Because of subsequent time restraints, this variable was not entered into the analysis (see the results of Phase II). Of the data that were available from each country, the following was found for each variable:

Household -- The household or dwelling unit (U.S.) generally has the same characteristics and is intended to identify the trip making unit in each case. It is felt that any differences between countries would have a very minor (if any) effect on the analysis in Phase II. In addition to considering the size of each transportation study, the types of city (e.g., industrial, agarian), location, and relative age should also be considered in Phase II to obtain a cross-section of data. These additional details were supplied by each country or were obtained from other sources. In order to easily develop the household level trip generation relationships, the household socio-economic data had to be in a format such that it could be combined with the trip information from that same household. This has been accomplished through the use of a computer program (DUSUM) described in Appendix C of this report (see also next section). To apply this program, each

household record and each trip record for that household must be identified by a unique number (sample or sample-zone number combination). This requirement was met in the data that were supplied by the participating nations for this project.

Trip -- The proposed work plan assumed the use of linked weekday person trips. This requirement was satisfied by those data sets that were finally used in the project. The data sets were particularly screened to achieve this criterion. Persons making trips that are included in the data range from all persons to those only 6 years old and older in the household. Some differences may be detected here in person trip making, although it is not felt that this would be significant. Most of the trip data represented is for persons 5 or 6 years old and older, as this is the age that trip making or the need for trip making could become significant.

Family Size -- The definition of persons included in the family size is essentially the same for all data sets.

Trip Purpose -- Although a relatively fine stratification of trips by purpose showed variances, when trips were examined by a few major categories these differences became minor. It appeared that the trip purpose stratification would not present any problems.

Mode -- As for trip purpose definition, there was a wide variety of modes represented in the data. If, as indicated in the original proposal, the trips were analyzed first as person trips and then split into public transit, private auto, and perhaps, bicycle, it was felt the variety of modes included in the data would not constitute a serious problem. One additional mode that could be studied separately, except for the U.S., was motorcycle. The modes in the U.S. data did not include either bicycle or motorcycle.

Income -- Initially it was felt the difference in this data item would perhaps, be the most difficult to reconcile, both because it is a primary ingredient in the proposed analysis and because of the differences in income categories. Additional, more basic considerations, such as differences in disposable income, which would bear on the ability to develop a generalized model needed to be considered also. These are discussed in the next section. In analyzing the income variable, all monetary ranges would be adjusted to ranges for a common year (1970 was chosen) to account for inflation in the respective country. Each monetary unit would then be converted to equivalent U.S. dollars for 1970. Income scales for pounds, guilders, Deutsche Marks, or dollars could be indicated on the appropriate relationships or in conversion table formats.

Auto Ownership -- There appears to be no major difference in the definition of autos owned or autos available between countries. An auto was generally included in the count if it was available for personal use even though it may have been a company car or taxi.

Net Residential Density -- This information was not readily available initially, but could be developed from supplemental data. The density of the zone of residence (the zone in which the household is found) or the census tract in which the household is found would be, it was felt, sufficient information to define this variable. The proposal was for the development of relationships by three (or four at the most) density categories (e.g., low, medium, high).

Workers in the Household -- This definition varied somewhat between countries and within countries. It resulted that this variable was not utilized in Phase II.

Students -- The number of students in each household was difficult to determine. The U.S. and the United Kingdom information on the household record did not include number of students. "Student" appeared under job description or occupation on each person record for at least two studies in the United Kingdom and one of the studies in the U.S. The information supplied from the Netherlands

indicated that the number of students in the household would be available for all transportation studies except one. It was not available from the German data.

Location of Household -- Thesedata would have to be developed from external sources. A suggested approach was given in the previous section of this report.

Persons Per Auto -- This information is not shown for the Netherlands' studies nor was it available from the German data. The total persons in the auto is shown on the trip records for each of the United Kingdom and the U.S. transportation studies and was felt to be compatible.

CONCLUSIONS

As a result of the Phase I effort a report was produced (portions of which have been integrated into the previous section of the report), and a second experts' meeting was convened in London, October 18-19, 1973 to discuss the findings. Agreement was reached among the delegates that there was sufficient compatibility between the various data sets to permit exploration and development of the proposed travel forecasting procedure.

PHASE II

INTRODUCTION

Phase II of the project dealt with the exploration of various trip generation relationships with the objective of developing a generalized set of models. Responsibilities of participating nations included supplying the necessary transportation study home interview data in the form of computer tapes and reports to the U.S. As a result of the second experts' meeting, additional information was to be supplied:

1. Format of the data records and content of each field in each record.
2. Information needed to process the data (e.g., are the tapes in BCD?, seven or nine track?, logical record length, etc.).
3. Supporting information on each city (e.g. type of city, "character," etc.).
4. Net residential density of each traffic analysis zone.
5. Location of each zone within each urban region by major categories (e.g., in-town, near suburbs, far suburbs).
6. Zone map of each region.
7. Any existing relationships that could be used as a guide or bench mark for the analysis in Phase II.
8. A time-of-day profile for work trips.

It was hoped that data from at least two cities in each participating country would be available for the analysis. Such criteria as format of

data, size of city, character or type of city, etc. were to be used in selecting the data sets. In the final analysis, however, availability proved to be the most critical criterion. In all, six data sets from Europe and four from the U.S. were used initially in the study:

1. Eindhoven, Netherlands and four surrounding cities
2. Tilburg, Netherlands and two surrounding cities
3. Arnhem, Netherlands
4. Hamburg, Federal Republic of Germany
5. Manchester, England
6. Lincoln, England
7. Washington, D.C.,USA
8. Texarkana, Texas, USA
9. Charlotte, North Carolina, U.S.A.
10. Nationwide Personal Transportation Survey, U.S.A.
11. Sacramento, California, U.S.A.

Table 2 describes major characteristics of each of the cities or survey data analyzed. Additional material and references, such as reports of national or other travel surveys, were used where appropriate to augment the study data used in the analysis.

The U.S. was responsible for developing or modifying any computer programs necessary to process the data and for conducting the analysis and preparing the final report for review by the participating nations.

Table 2

CHARACTERISTICS OF STUDIES ANALYZED

Study	Year Data Collected	Sample Size	Population	Type
Eindhoven Neth.	1970	14,000 (20%)	270,000	An agglomeration covering 5 municipalities of which Eindhoven most important. A modern industrial town in south. Fifth largest in Netherlands. Covers three municipalities, Tilburg is most important with 154,500 population and recent rapid growth
Tilburg Neth.	1972	6,000 (10%)	185,000	
Arnhem, Neth.	1972	(20% selected areas)	250,000	
Hamburg, FRG.	1971	(Data in report)		
Manchester, G.B.	1966	25,200	2,500,000	A conurbation
Lincoln, G.B.	1970	3,800	100,000	Free standing medium size town
Washington, D.C. U.S.A.	1968			
Texarkana, Texas		(Data in report)		
Nationwide Personal Transportation Survey	1969-70	6,000	--	
Charlotte, North Carolina		(Data in report)		
Sacramento, California				

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METHODS OF ANALYSIS

The development of the household trip generation relationships was accomplished using category or cross-classification analysis. Basic trip and household socio-economic data from transportation study home interview surveys are merged to form a basic household record with trip data appended. These records can then be processed by computer programs designed to cross-classify households by given categories of specified independent variables.* Discussion of data preparation, the computer programs, and the program output is contained in the following paragraphs.

Preparation of Data

Several transportation studies were chosen from each of the participating countries to serve as a data source for Phase II analysis. Available data needed to be in household and trip record formats (card images) with a unique sample identifier on each household and trip record. The trip records were assumed to be edited and linked when received by the U.S.

From the separate household and trip records, a single dwelling unit summary record was constructed. This single record contained all pertinent household socio-economic data including (1) family size, (2) income, and (3) autos available. The record also contained the number of home-based trip productions for the household by several major trip purposes (e.g., work, shop, school, other and non-home

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* It should be noted here that the relationships shown for Hamburg, Germany were developed from published reports.

based) and by each of several modes.

A separate field on each summary record contains a trip purpose or mode. Any additional data from supplemental sources could be added to the record. The dwelling unit summary record then serves as the base data source for the relationships that were developed under Phase II. Using the dwelling unit summary record, and several computer programs, a series of relationships (constructed as matrices) were developed.* A separate set of relationships was developed for each city. The basic matrices were then converted to graphical displays similar to those shown in the Introduction to this report. These were needed to analyze the degree to which the relationships are comparable among various cities and countries, and to present the results efficiently and in an easily manageable format.

Programs Used

Two main programs were utilized to develop the dwelling unit summary records (DUSUM) and the cross-classification matrices (XCLASS).[21/] Additional programs were used to process the original data sets so that they could be input to the DUSUM program. An additional program was used (PRKTAB) and modifications to XCLASS were made in order to achieve the desired cross-classification output.

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* See next section for a description of the computer program used.

21/ U.S. Department of Transportation, Federal Highway Administration, "FHWA Computer Programs for Urban Transportation Planning," Washington, D.C., July 1974.

Descriptions of DUSUM and XCLASS are contained in Appendix B. This Appendix also describes a matrix solving program (XSOLVE) that can be used to develop trip end estimates, given socio-economic input data. The use of this program has implications for the application of the trip generation procedure described in this report. The section on "Application of Developed Relationships" describes this in more detail. The PRKTAB program builds matrices similar to XCLASS, however, processing is a little different and percentages (e.g., transit trips as a percent of total trips) can be obtained directly from the program.

Program Output

Once the data sets were readable and acceptable for processing, program DUSUM was run to develop the dwelling unit summary record. Variables were specified (e.g. income, car ownership, family size) to be included in the output along with trips by purpose and mode. These data records were then processed by XCLASS or PRKTAB to develop the various matrices. To the extent possible development of the primary relationships was attempted, but limitations in the data or processing capabilities required the development of alternate relationship as discussed in the section on "Rationale for Study Analysis."

The results of matrix development runs were analyzed, the income values were converted to a constant year (1970), and then converted to U.S. dollars prior to plotting. In plotting, a smooth hand-fitted curve

was drawn through each of the data points.* The shape of the curves was governed in part by the data points themselves and by experience from other transportation studies. No attempt was necessarily made to connect each data point since, for this project, the general shape of the relationships was important and, for future regional estimations, this degree of precision is not warranted nor could it be reasonably expected with the level of analysis that was conducted. The specific patterns of the resulting relationships were, however, important and the general effects on trips by varying auto ownership and income levels was specifically required in the carrying through of this subproject.

After the relationships were plotted, additional "external" factors (particularly those relating to economic differences between nations) were considered in analyzing and comparing the relationships between cities. These considerations are discussed later in "Results--Other Relationships."

Assumptions Made in Processing the Data

Of necessity there were several assumptions that had to be made before processing the mass of data obtained from the participating nations. First, and most importantly, it was assumed that the data were clean (i.e., the data had been put through an editing routine) and the trip and household records could be used for the analysis without further modification.

It was also assumed that the trips were linked (i.e., stages of a journey to serve a passenger or to get to another mode) were combined in

* At this point, the data in reports representing Hamburg, Germany were plotted and became an additional data set for the remainder of the project.

some predefined way to maintain the ultimate purpose of the journey. This was defined in Phase I and stipulated in the work plan as an important consideration in the analysis.

A third assumption regarded trip adjustments. Normally trips obtained from household interviews will be under-reported for a number of reasons: The interviewee forgot a trip he made, overlooked a trip some other family member made, or a family member that made trips on the travel day was not present at the household on the interview day. Trip data from the home interview are usually adjusted upward using counted traffic as a bench mark. Since the household cross-classification process using DUSUM and XCLASS uses the unexpanded trip data, each record being a trip, any needed adjustment is not incorporated. The adjustment factor, when required can be applied at any of several points during the process: (1) To the trip rates in matrix form, (2) to the resultant trip production estimate after the matrix is applied, or (3) the analyst can take into consideration the fact that estimated trip volumes are likely to be somewhat low when evaluating trip assignment results.

In the analysis in Phase II, this adjustment was not taken into consideration. It was felt that this project was to explore the idea of a generalized modeling process and that the lack of this adjustment would not limit this objective. For any actual application of these trip rates in an operational transportation study, the adjustments would have to be

made. Trip rates in this project based on information in published reports will normally be based on adjusted trip data.

In all cases the curves shown in this report were hand fitted to the points derived from the cross-classification analysis. No function or computer program was used to attempt to fit the data more precisely. Consideration was given to the number of observations representing a particular data point when plotting the relationships and, in some cases matrix cell values represented by very few (less than 10) observations were ignored.

RESULTS

The results of Phase II analysis are presented in the following sections of this report. Each model or relationship is presented separately and comparisons are made between the cities for which results were available. No conclusions are drawn in this section of the report. This is left to the following section dealing with the application of the developed relationships in which some general observations are made.

Summary of Results

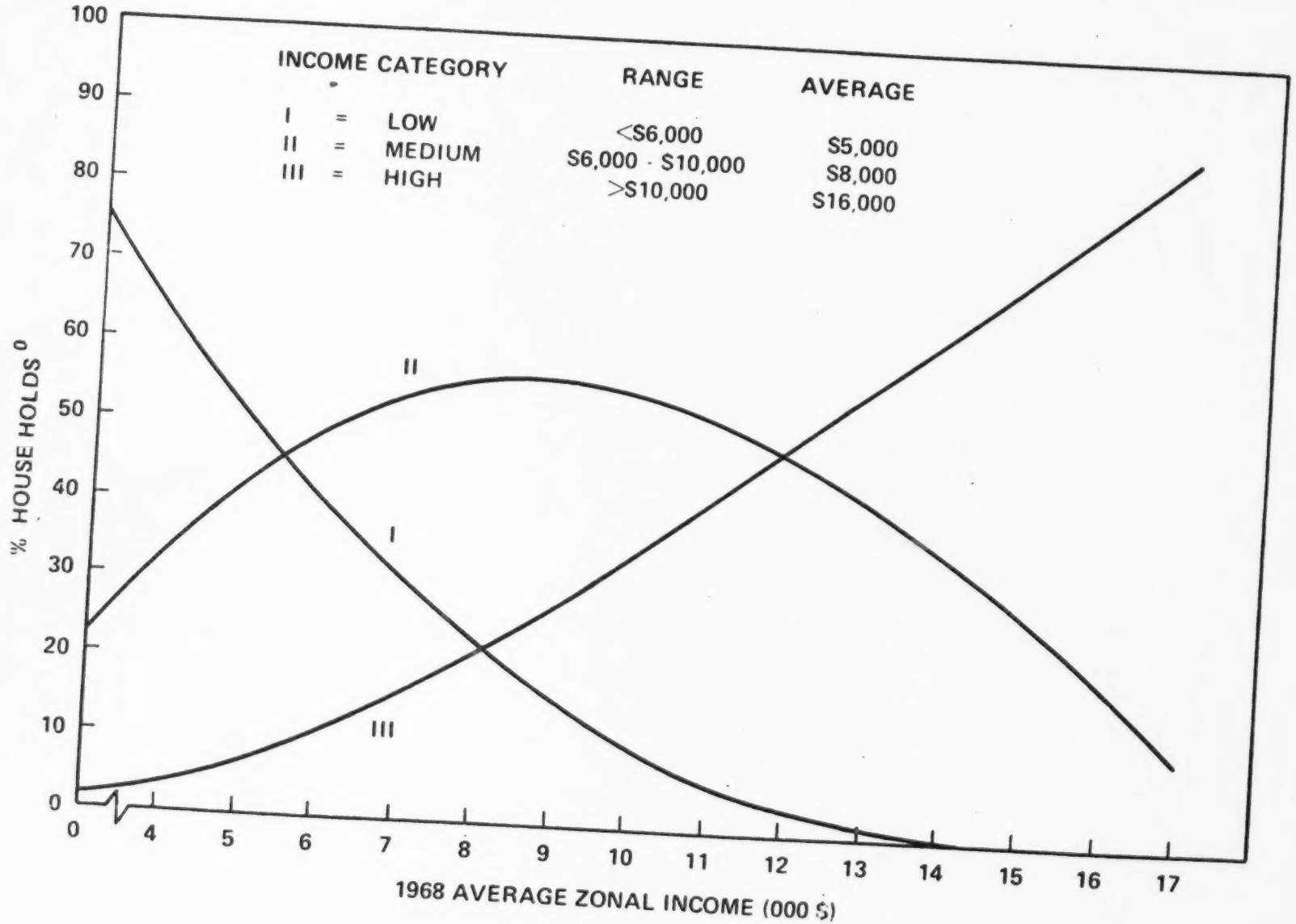
The curves in general follow preconceived notions about differences between European and U.S. characteristics and levels of auto ownership and trip making. Observations, along the same line on a national level were discussed in the section on "The Current Problem" earlier in this report. The European curves tend to be fore-shortened, not extending over the range of income values that the U.S. cities do, generally reflecting lower relative income levels. Single car households in the European cities are higher and multiple car households are lower as a percent of total households at a given income level when compared to U.S. city data. When family size is introduced as a third independent variable the difference is not quite as pronounced in the larger families. In the single person households auto ownership (a single car) is much higher in the European cities analyzed than in the U.S. and the incidence of owning a car occurred over a much narrower, and lower, income range. It would seem that the single person households contribute most to the differences in auto ownership.

Trip making generally extends over the same range for single car owning households, roughly 6-14 total person trips per household, depending on the income level. Multi-car households vary a little more, ranging from about 12 to 20 trips per household for one group of cities (both U.S. and European) and from 6 to 14 for another group, again for both U.S. and European cities. The greatest difference between cities is found in the 0-car households which show a relatively high trip rate in Europe when compared to the U.S. curves. This reflects the higher transit trip making in Europe, at least for non-car-owning households. This fact is generally reflected in the curves for percent transit trips by income range which are lower for the U.S. cities. Another difference in the percent transit curve is that it does not vary considerably in trips per household over the range of incomes. At the same time, auto trips in the European cities vary considerably over income from about 20 percent to 70-90 percent of total household trips. For the U.S. cities, auto trips vary over a narrower range constituting about 70-80 percent of total trip productions over all income levels. On a trip per household basis, however, transit trips for both U.S. and European cities do not vary much at all and for both range from about one to two trips per household on the average.

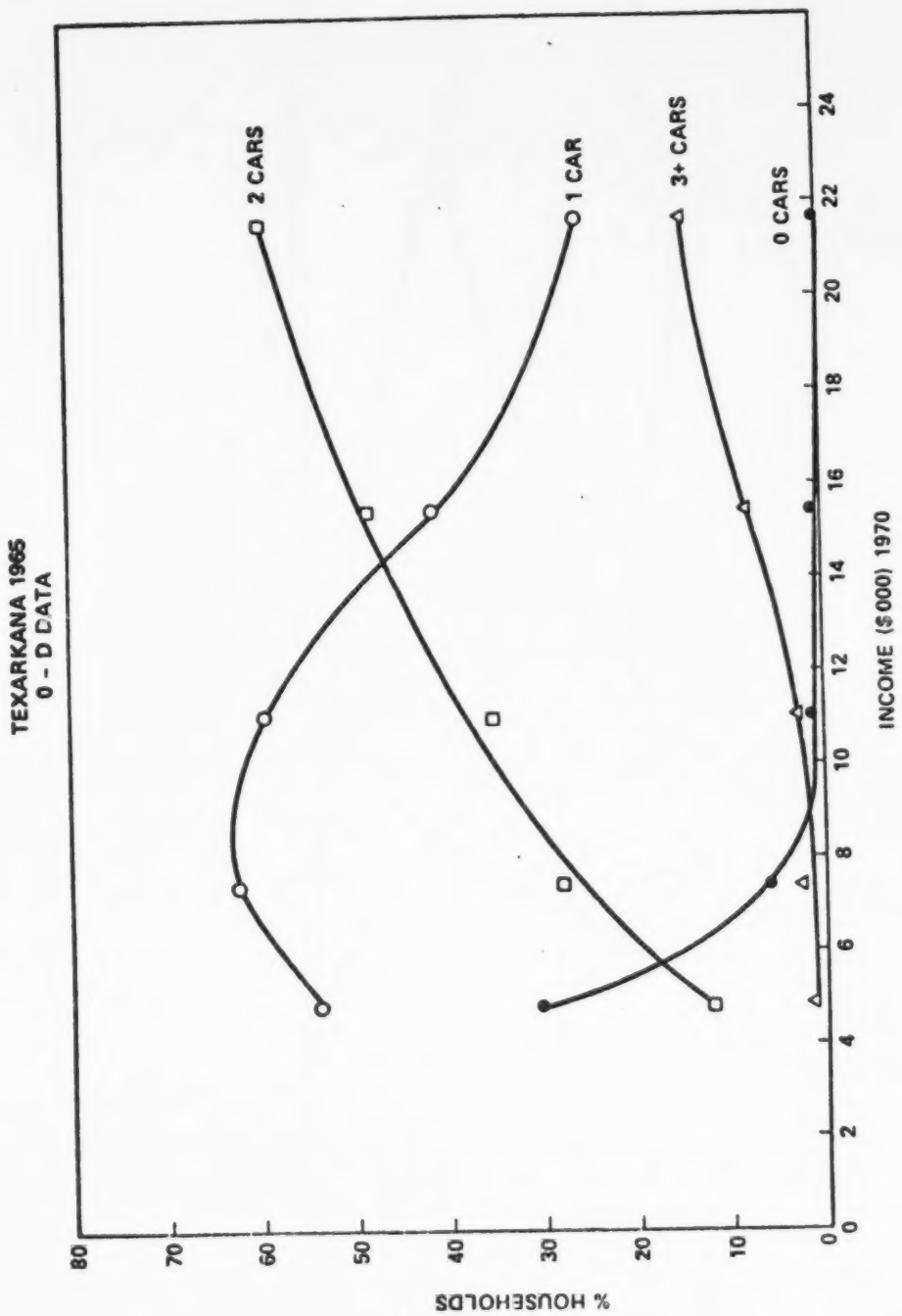
In the following sections the plotted results from the cross classification analyses are presented.

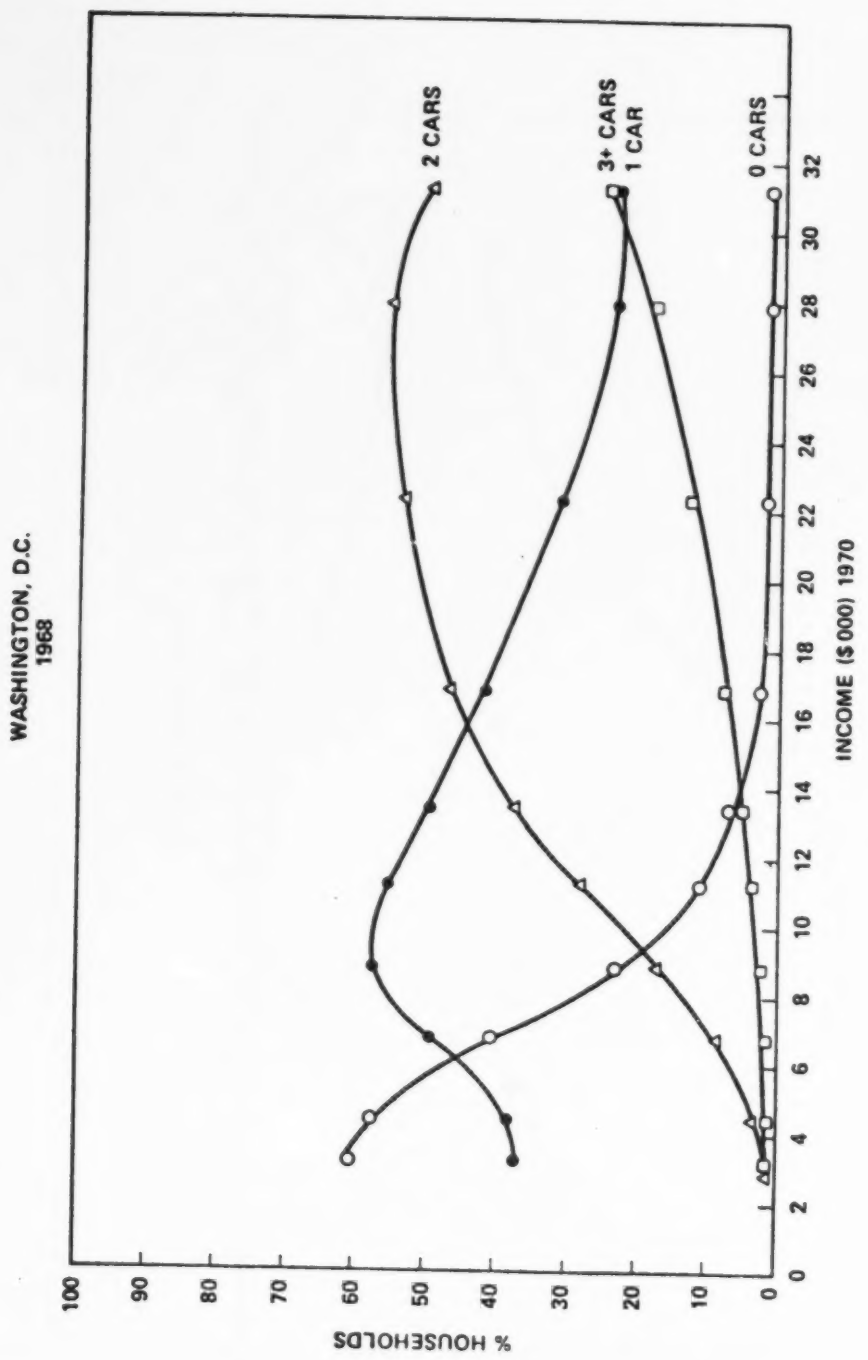
CURVE 1

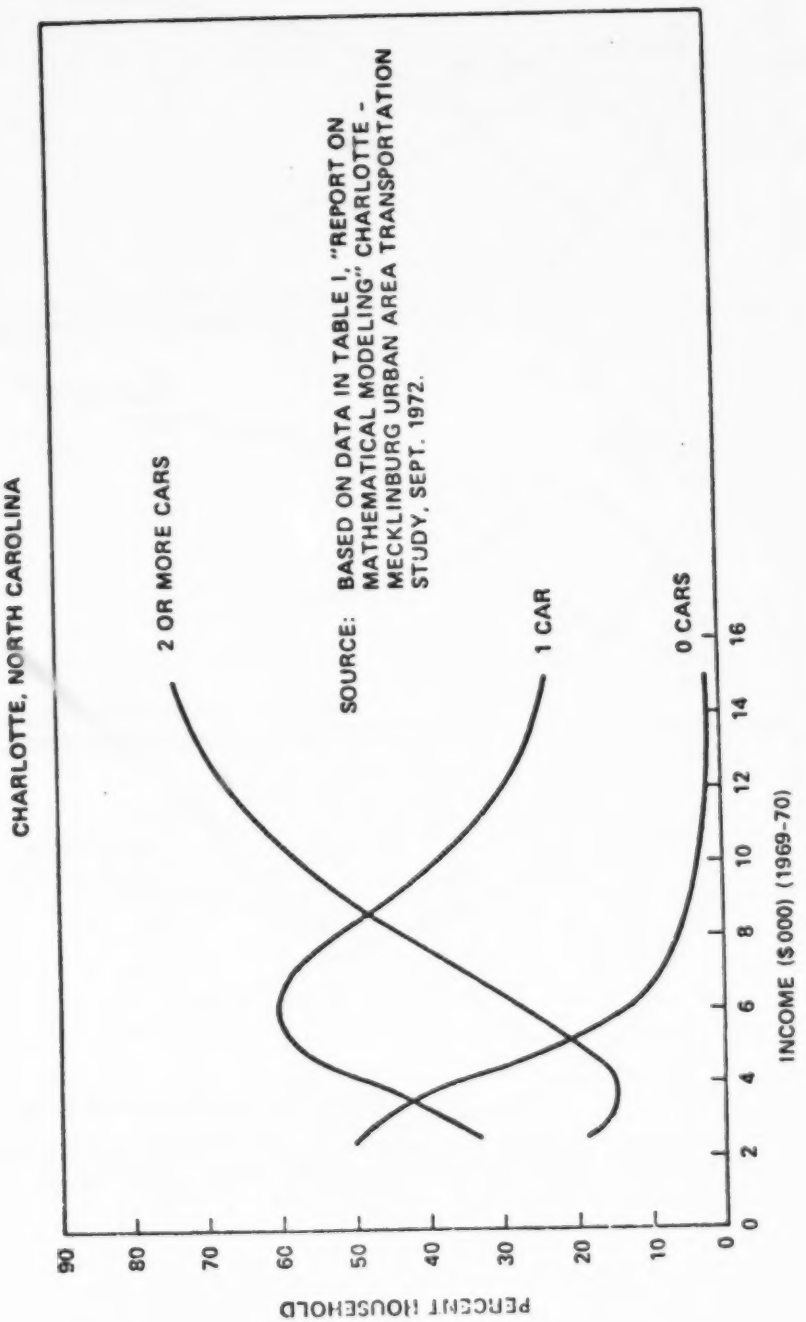
AUTO OWNERSHIP


INCOME CATEGORY
RANGE
AVERAGE
I = LOW
II = MEDIUM
III = HIGH
<S6,000
S6,000 - S10,000
>S10,000
S5,000
S8,000
S16,000
% HOUSE HOLDS
I
II
III
1968 AVERAGE ZONAL INCOME (000 $)

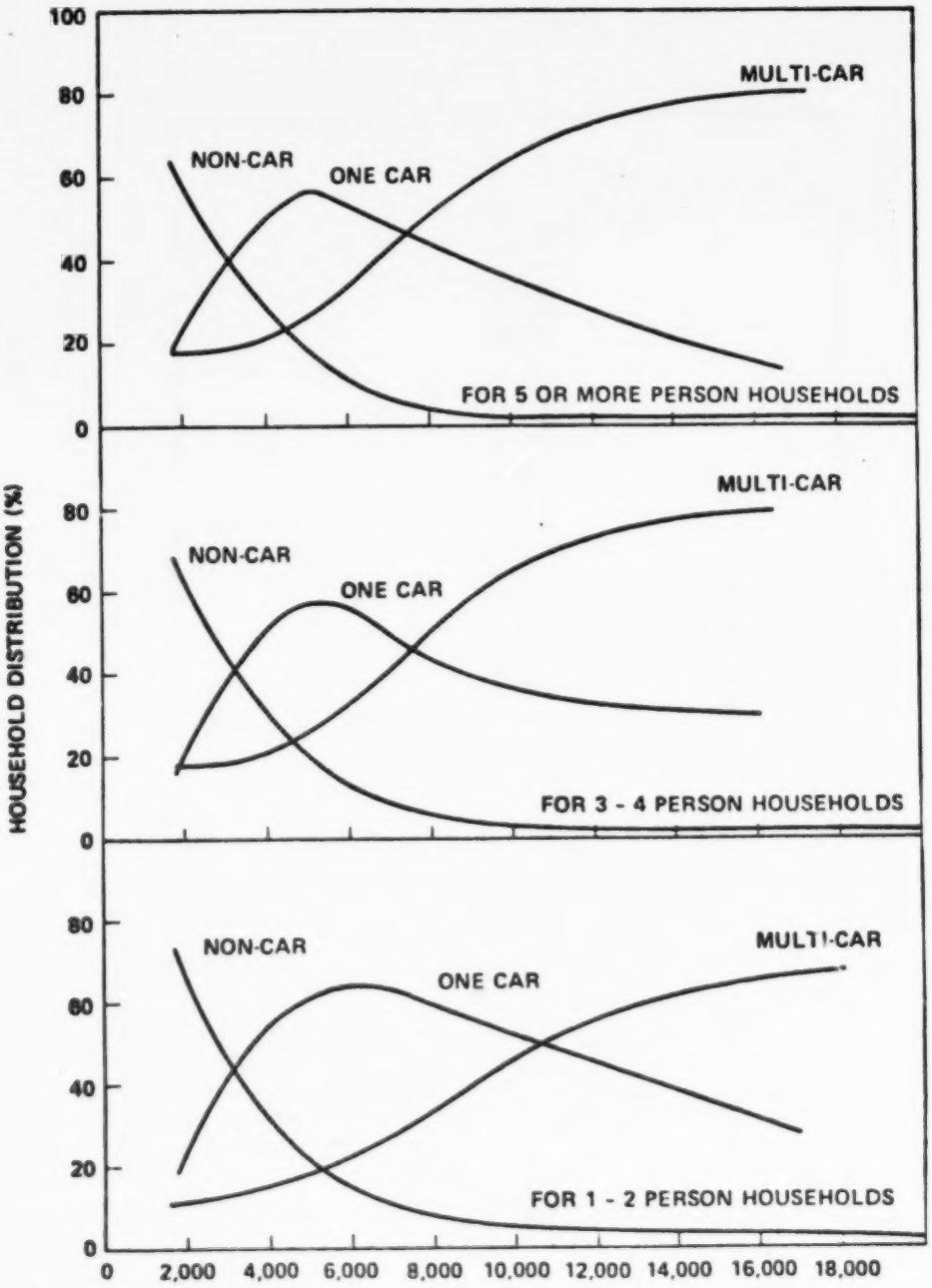
CURVE 1

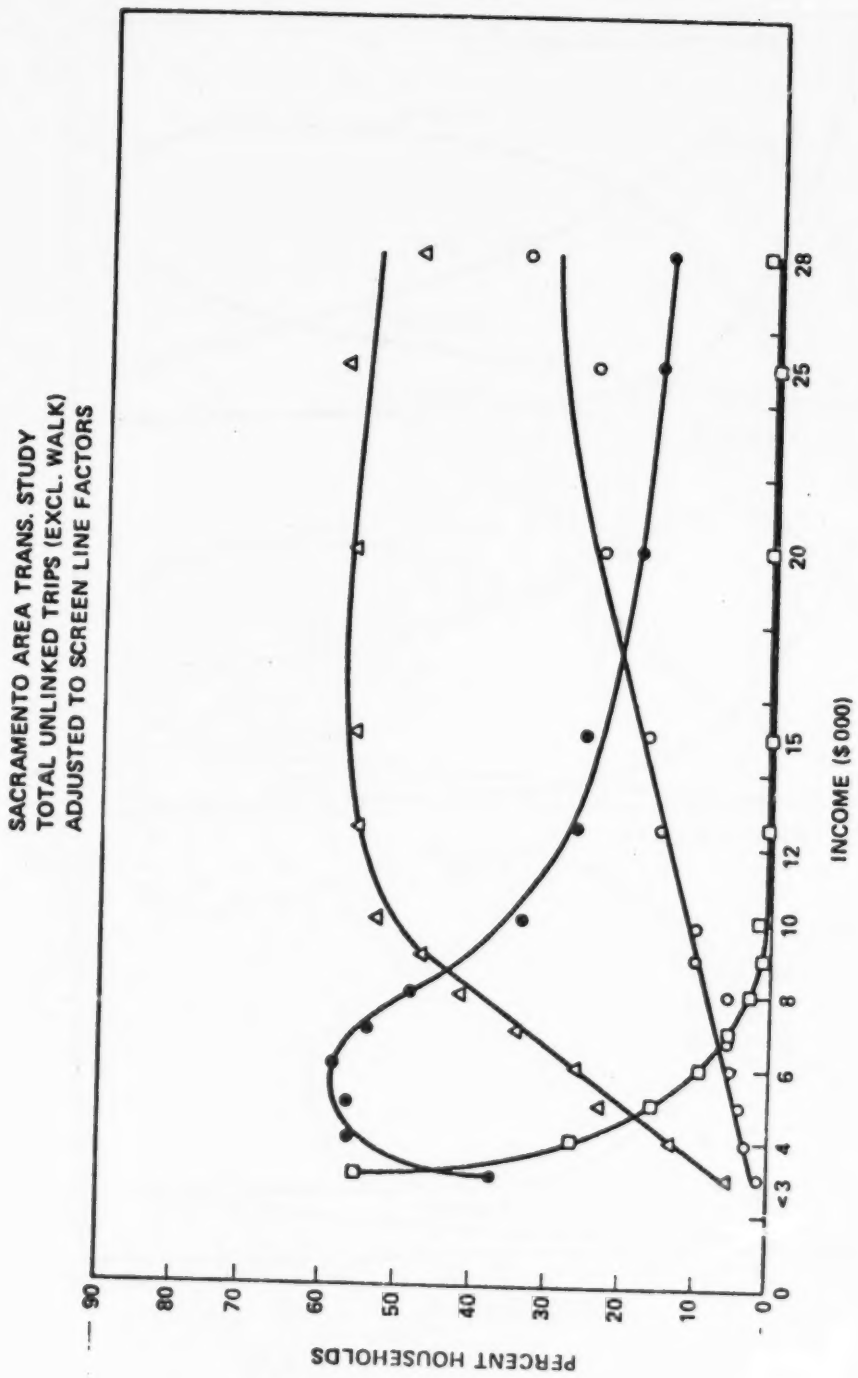

TEXARKANA 1965
0 - D DATA
2 CARS
1 CAR
3+ CARS
0 CARS
% HOUSEHOLDS
INCOME ($000) 1970
0
10
20
30
40
50
60
70
80
0
2
4
6
8
10
12
14
16
18
20
22
24

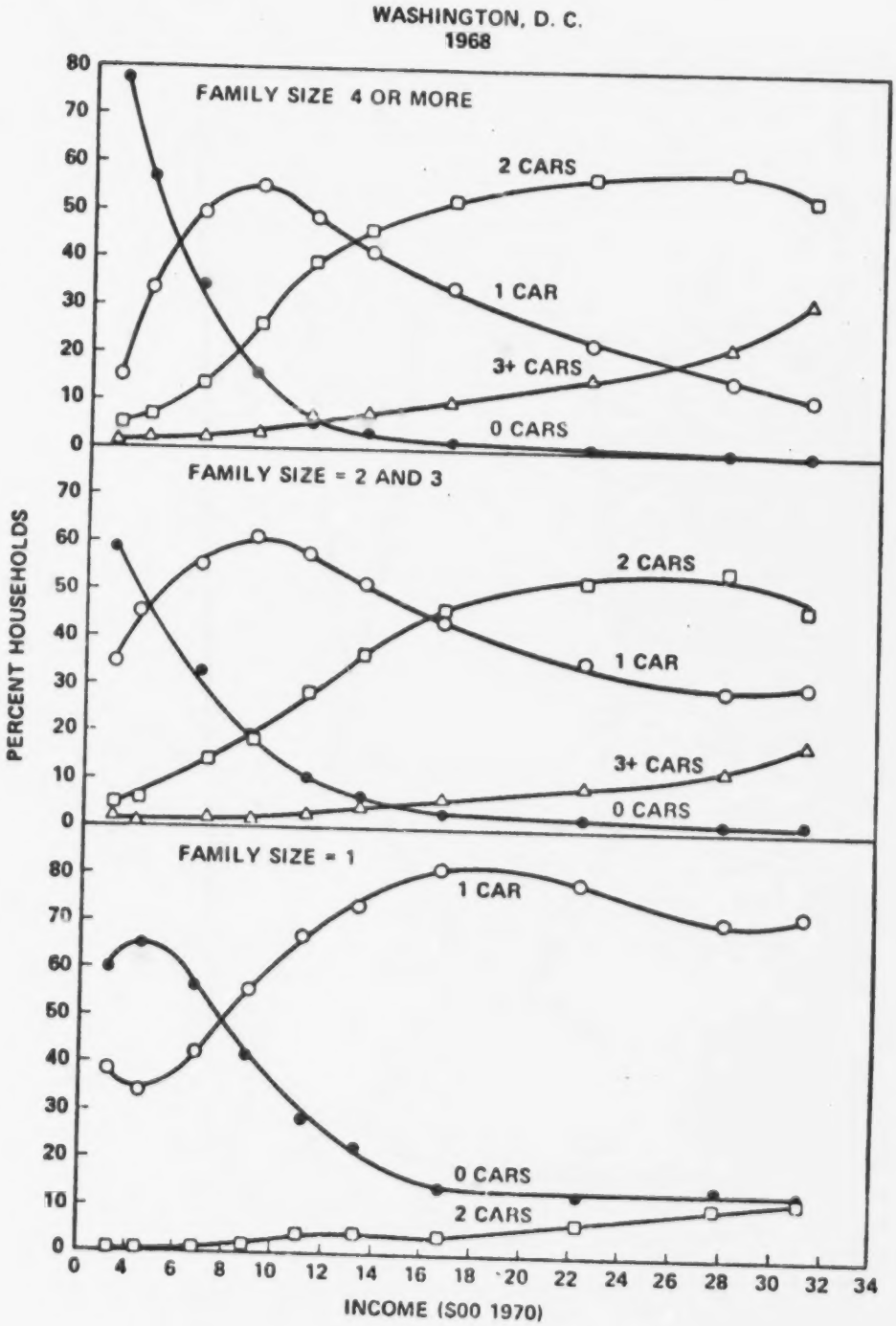

WASHINGTON, D.C.
1968
2 CARS
3+ CARS
1 CAR
0 CARS
% HOUSEHOLDS
INCOME ($000) 1970
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32


CHARLOTTE, NORTH CAROLINA
2 OR MORE CARS
1 CAR
0 CARS
SOURCE: BASED ON DATA IN TABLE I, "REPORT ON MATHEMATICAL MODELING" CHARLOTTE - MECKLINBURG URBAN AREA TRANSPORTATION STUDY, SEPT. 1972.
PERCENT HOUSEHOLD
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
INCOME ($000) (1969-70)

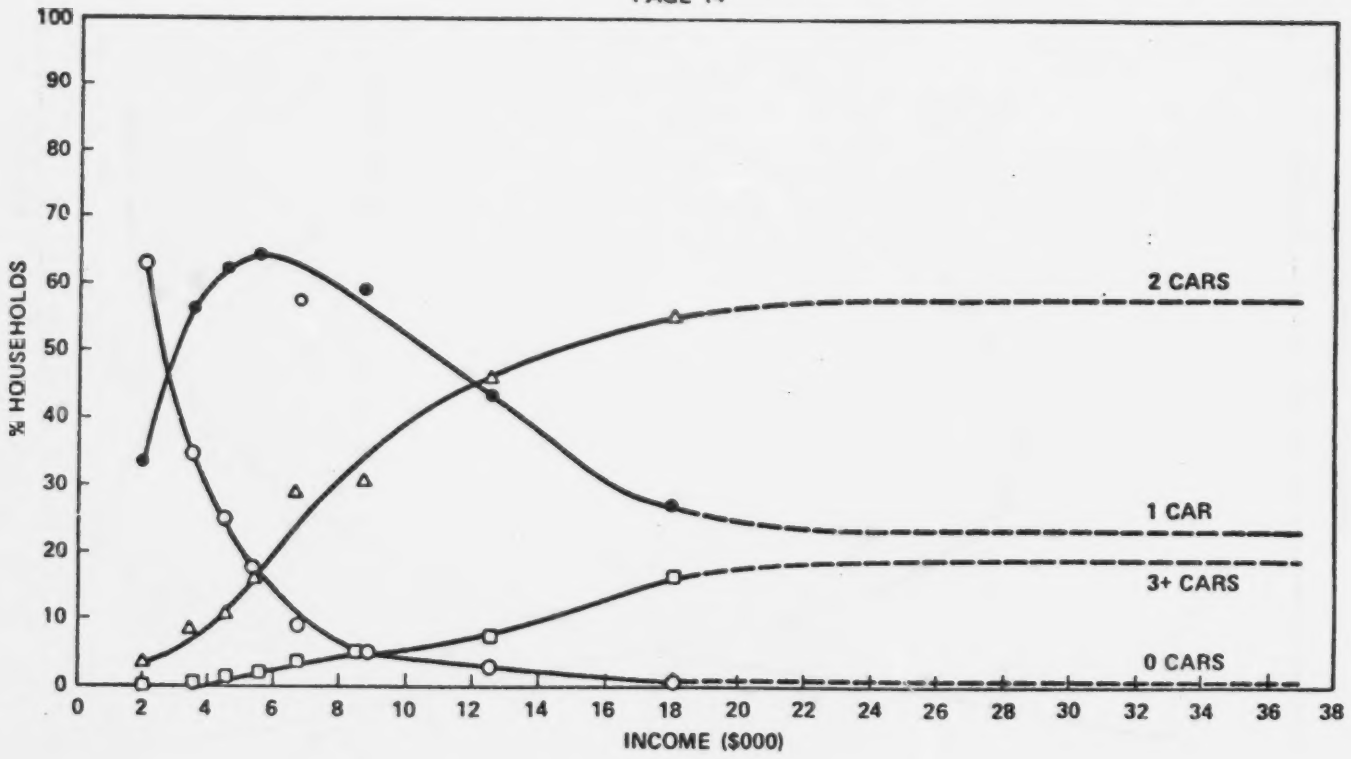
CAR OWNERSHIP MODEL
CHARLOTTE-MECKLENBURG TRANSPORTATION STUDY

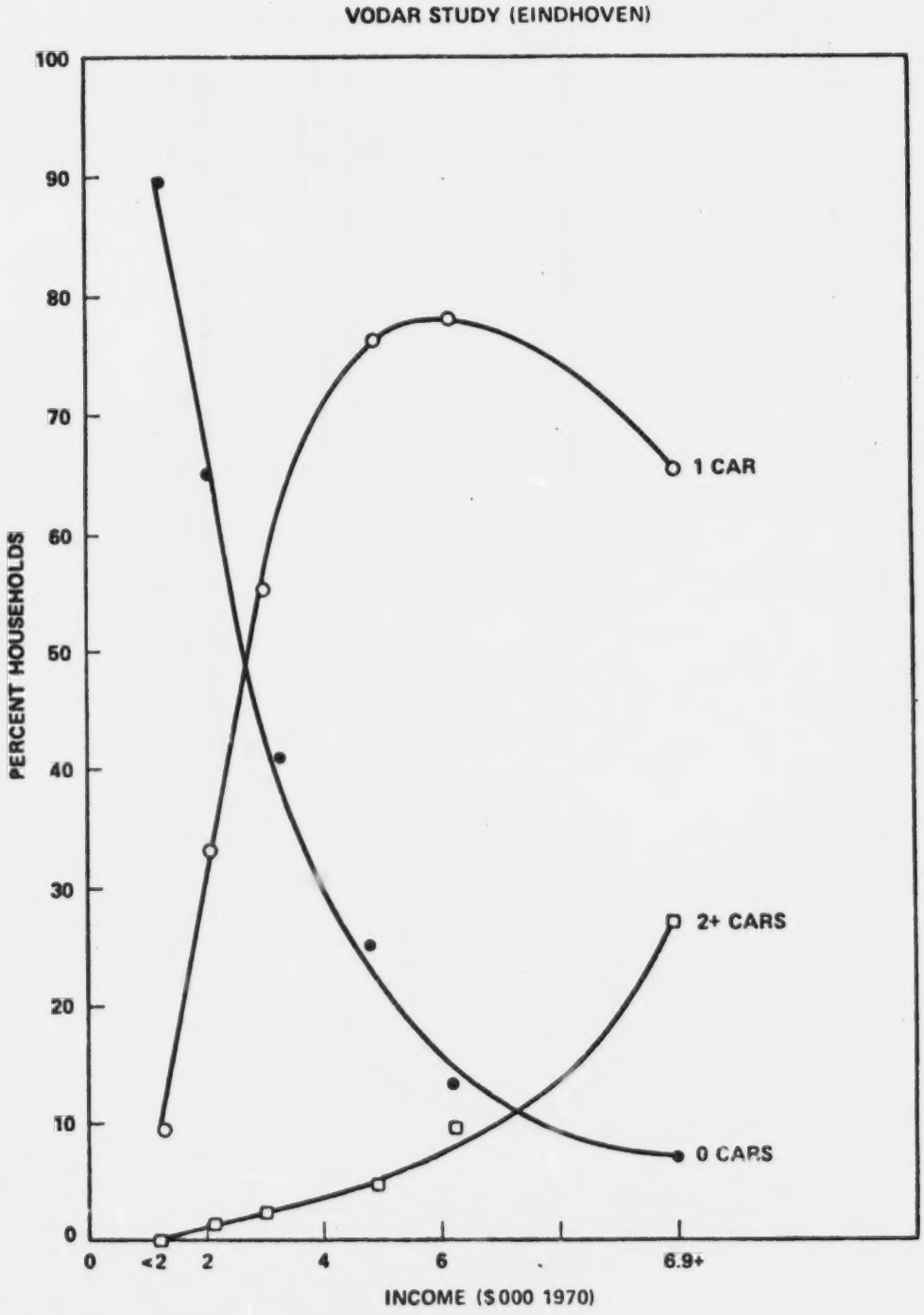


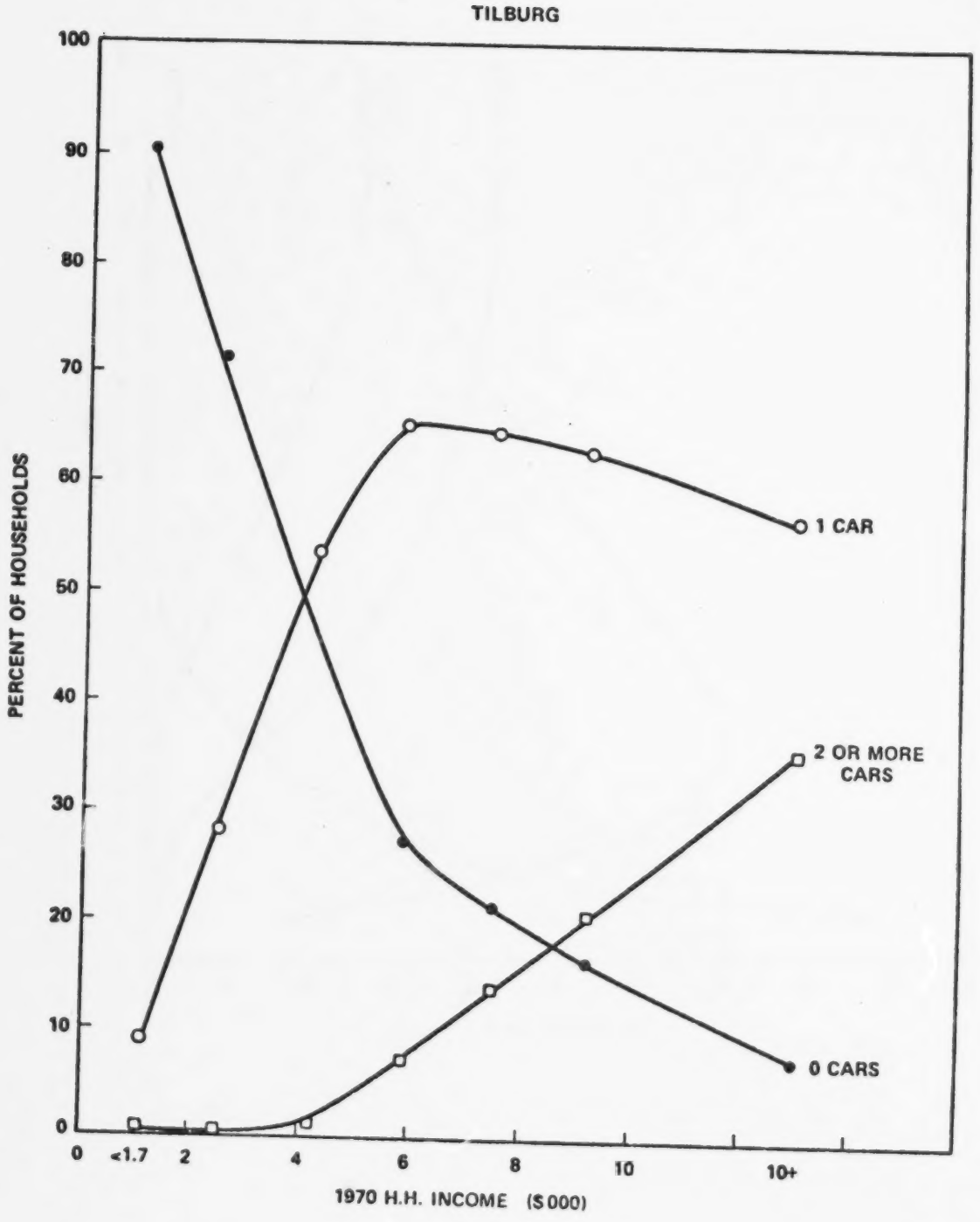

SACRAMENTO AREA TRANS. STUDY
TOTAL UNLINKED TRIPS (EXCL. WALK)
ADJUSTED TO SCREEN LINE FACTORS
PERCENT HOUSEHOLDS
90
80
70
60
50
40
30
20
10
0
<3
4
6
8
10
12
15
20
25
28
INCOME ($000)

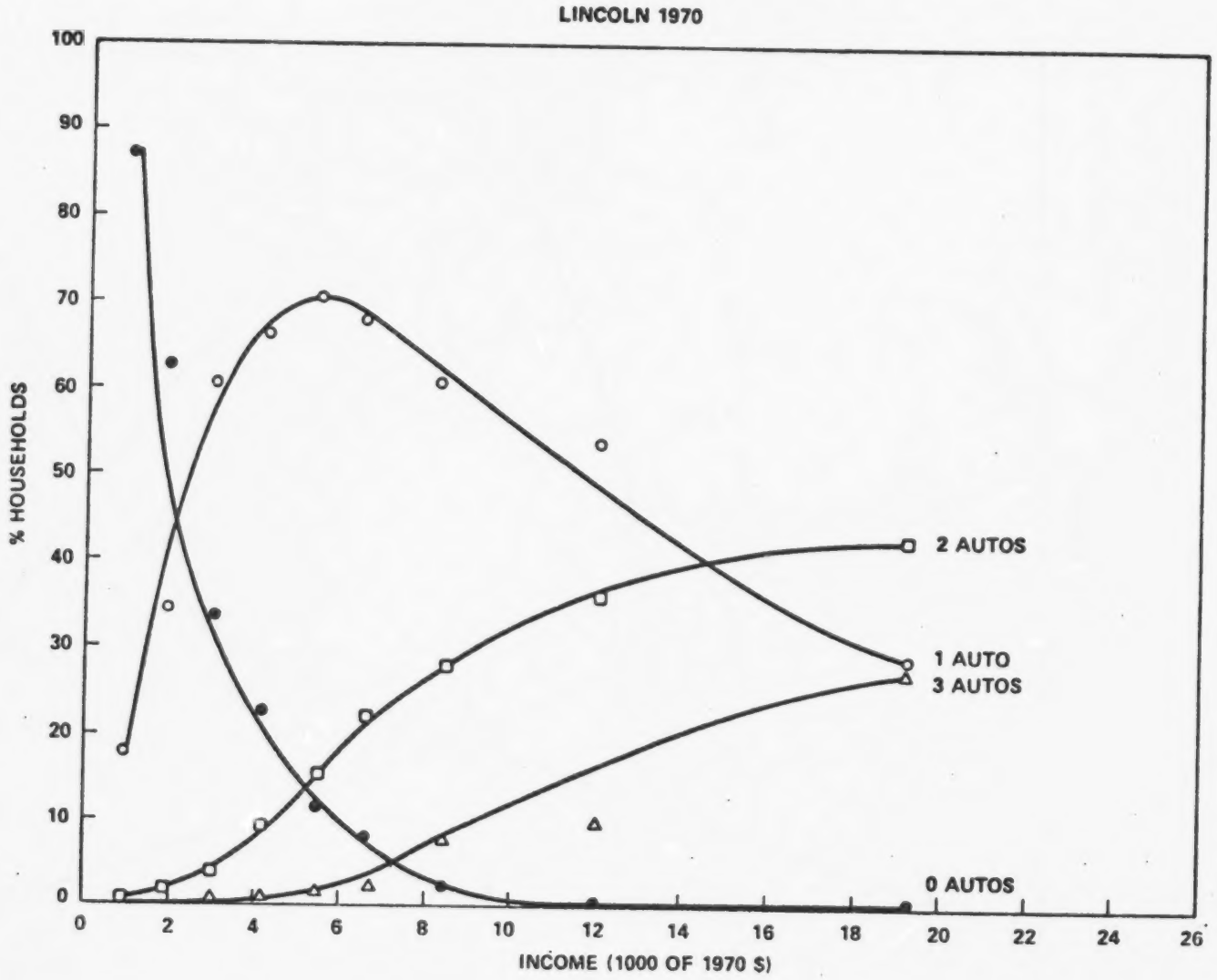

WASHINGTON, D. C.
1968
FAMILY SIZE 4 OR MORE
2 CARS
1 CAR
3+ CARS
0 CARS
FAMILY SIZE = 2 AND 3
2 CARS
1 CAR
3+ CARS
0 CARS
FAMILY SIZE = 1
1 CAR
0 CARS
2 CARS
PERCENT HOUSEHOLDS
INCOME ($00 1970)

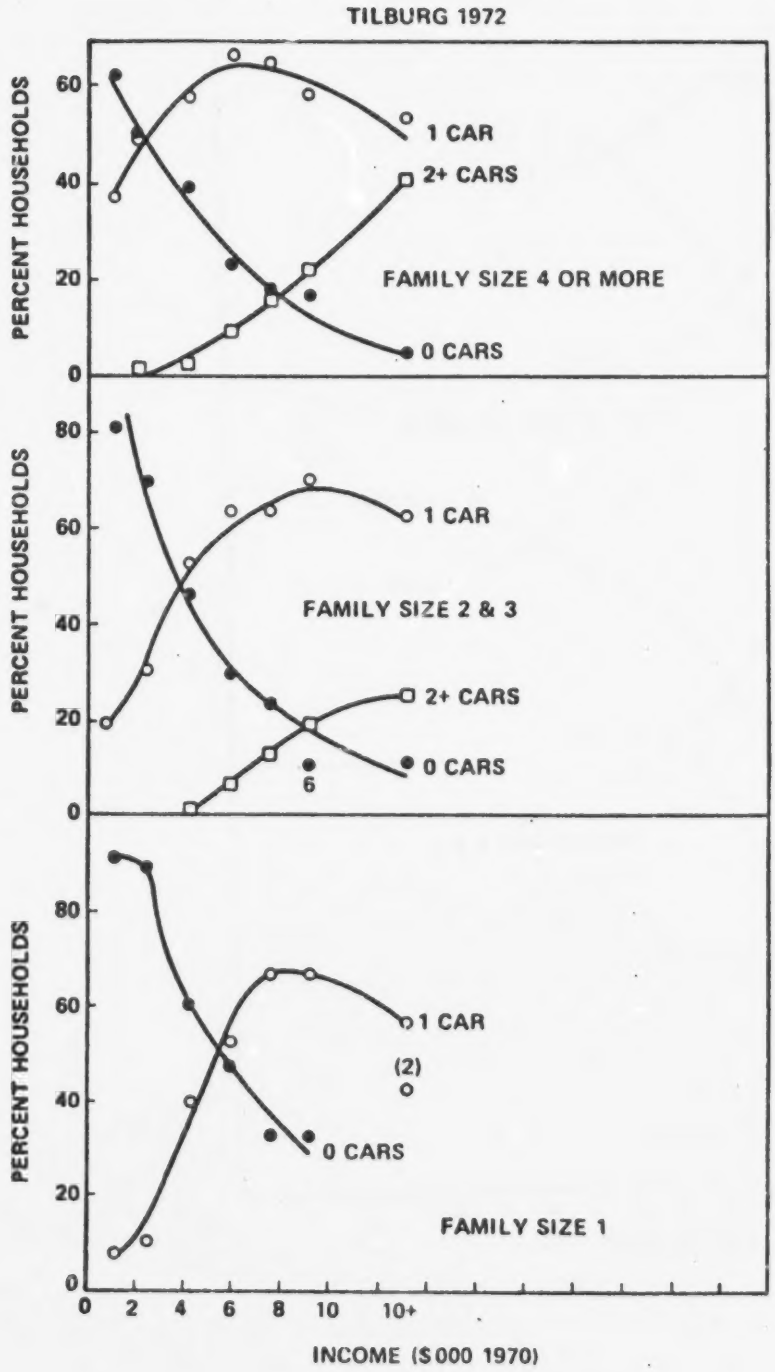
NATIONWIDE PERSONAL TRANSPORTATION SURVEY (1969-1970)
AUTOMOBILE OWNERSHIP
REPORT #11 TABLE 3
PAGE 14

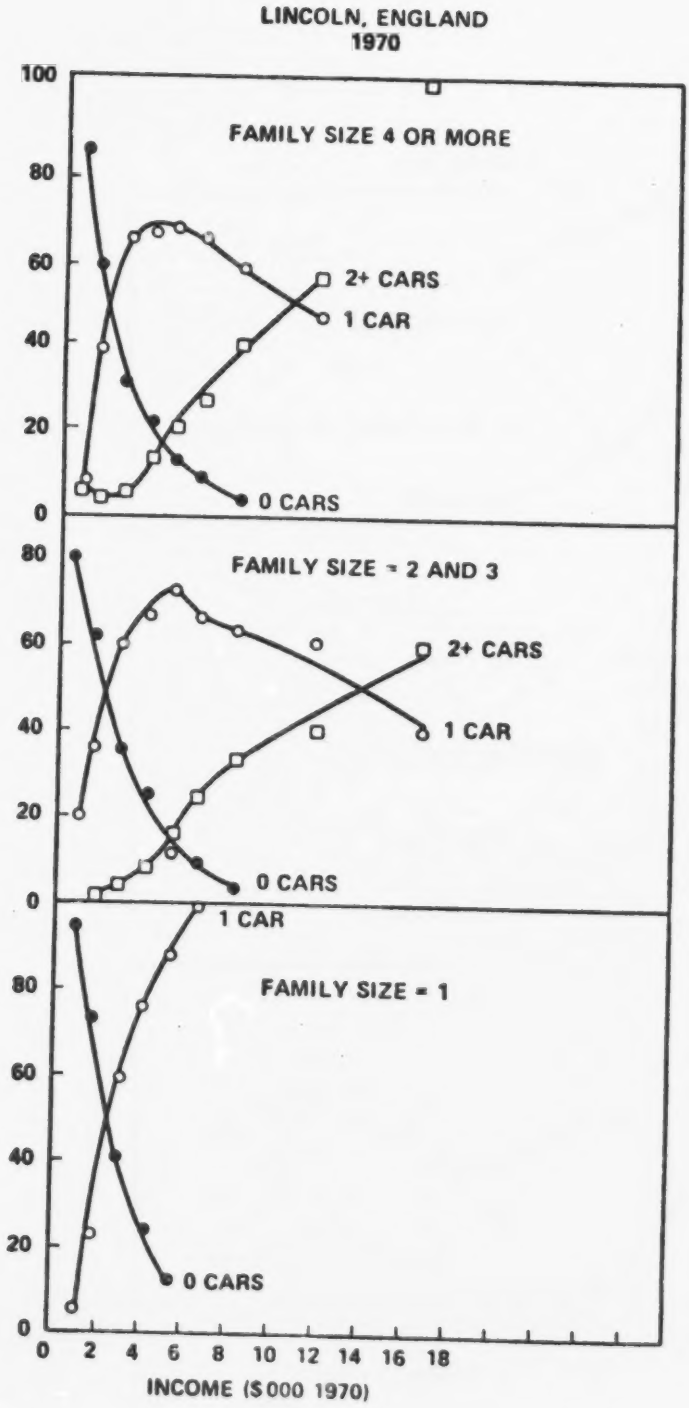



VODAR STUDY (EINDHOVEN)
PERCENT HOUSEHOLDS
100
90
80
70
60
50
40
30
20
10
0
1 CAR
2+ CARS
0 CARS
0
<2
2
4
6
6.9+
INCOME ($000 1970)

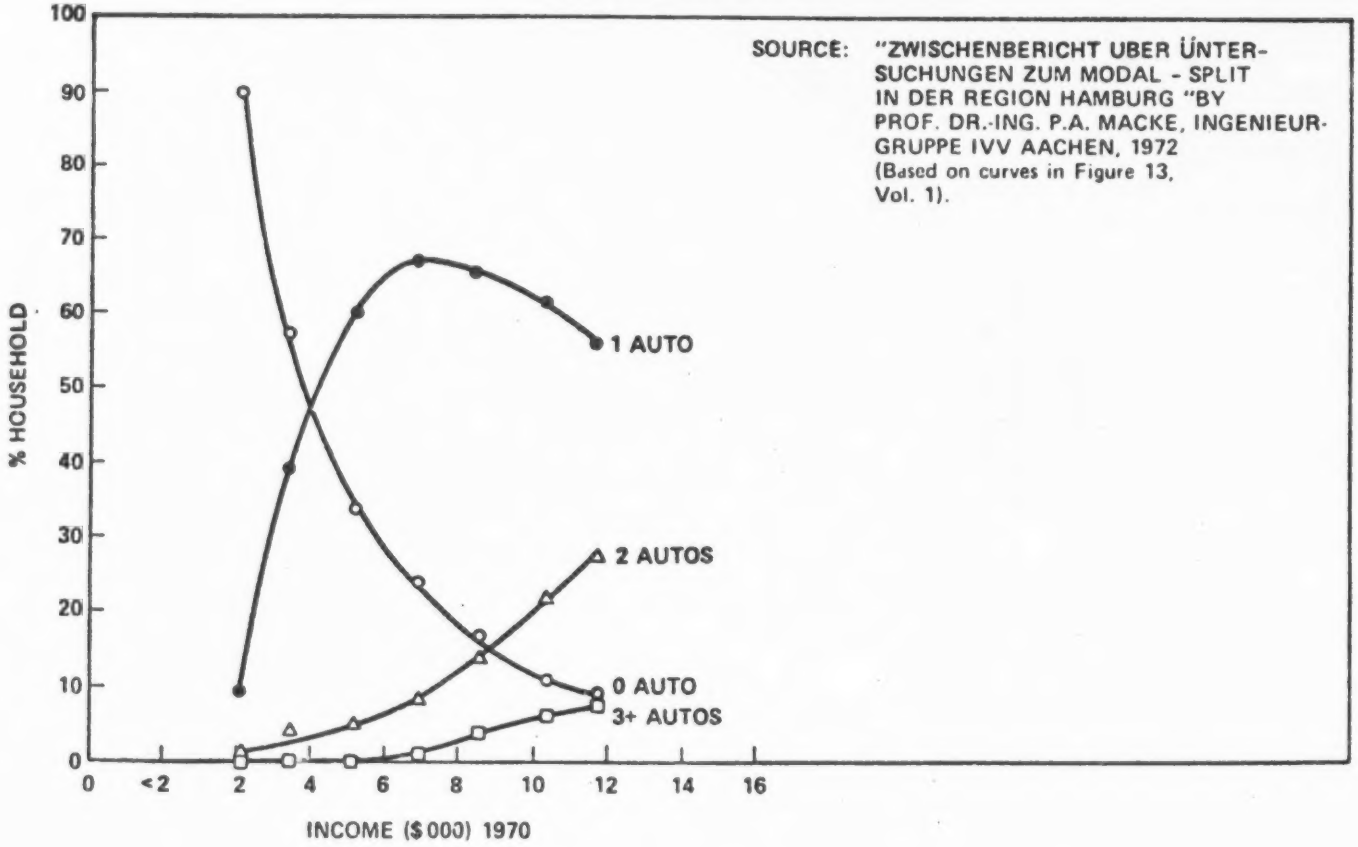

TILBURG
PERCENT OF HOUSEHOLDS
100
90
80
70
60
50
40
30
20
10
0
0
<1.7
2
4
6
8
10
10+
1970 H.H. INCOME ($000)
1 CAR
2 OR MORE CARS
0 CARS


LINCOLN 1970
% HOUSEHOLDS
INCOME (1000 OF 1970 $)
2 AUTOS
1 AUTO
3 AUTOS
0 AUTOS
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26


TILBURG 1972
PERCENT HOUSEHOLDS
60
40
20
0
1 CAR
2+ CARS
FAMILY SIZE 4 OR MORE
0 CARS
PERCENT HOUSEHOLDS
80
60
40
20
0
1 CAR
FAMILY SIZE 2 & 3
2+ CARS
0 CARS
6
PERCENT HOUSEHOLDS
80
60
40
20
0
1 CAR
(2)
0 CARS
FAMILY SIZE 1
0 2 4 6 8 10 10+
INCOME ($000 1970)


LINCOLN, ENGLAND
1970
FAMILY SIZE 4 OR MORE
2+ CARS
1 CAR
0 CARS
FAMILY SIZE = 2 AND 3
2+ CARS
1 CAR
0 CARS
1 CAR
FAMILY SIZE = 1
0 CARS
100
80
60
40
20
0
0 2 4 6 8 10 12 14 16 18
INCOME ($000 1970)

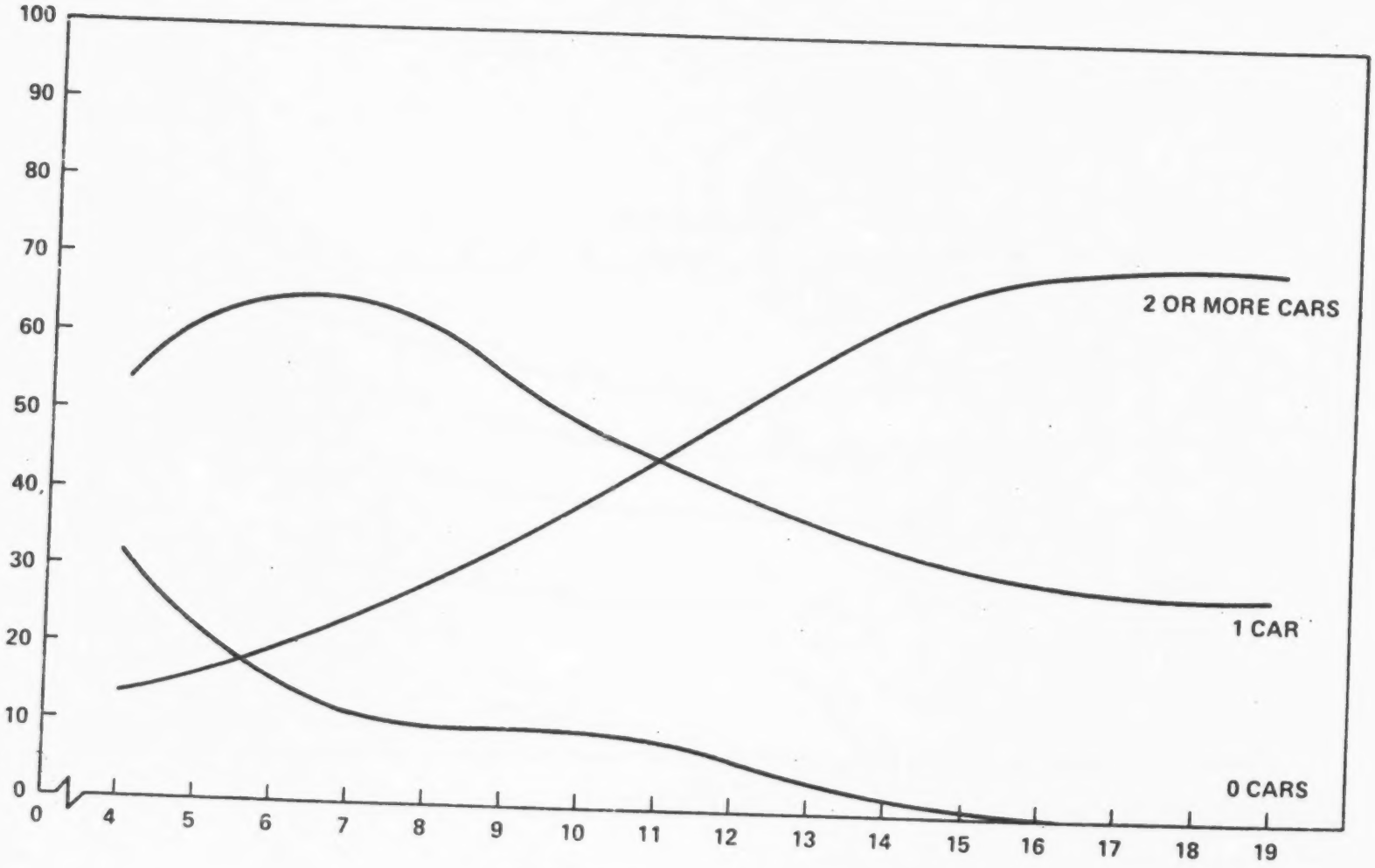
HAMBURG, WEST GERMANY, 1972



SOURCE: "ZWISCHENBERICHT UBER UNTERSUCHUNGEN ZUM MODAL - SPLIT IN DER REGION HAMBURG "BY PROF. DR.-ING. P.A. MACKE, INGENIEURGRUPPE IVV AACHEN, 1972 (Based on curves in Figure 13, Vol. 1).

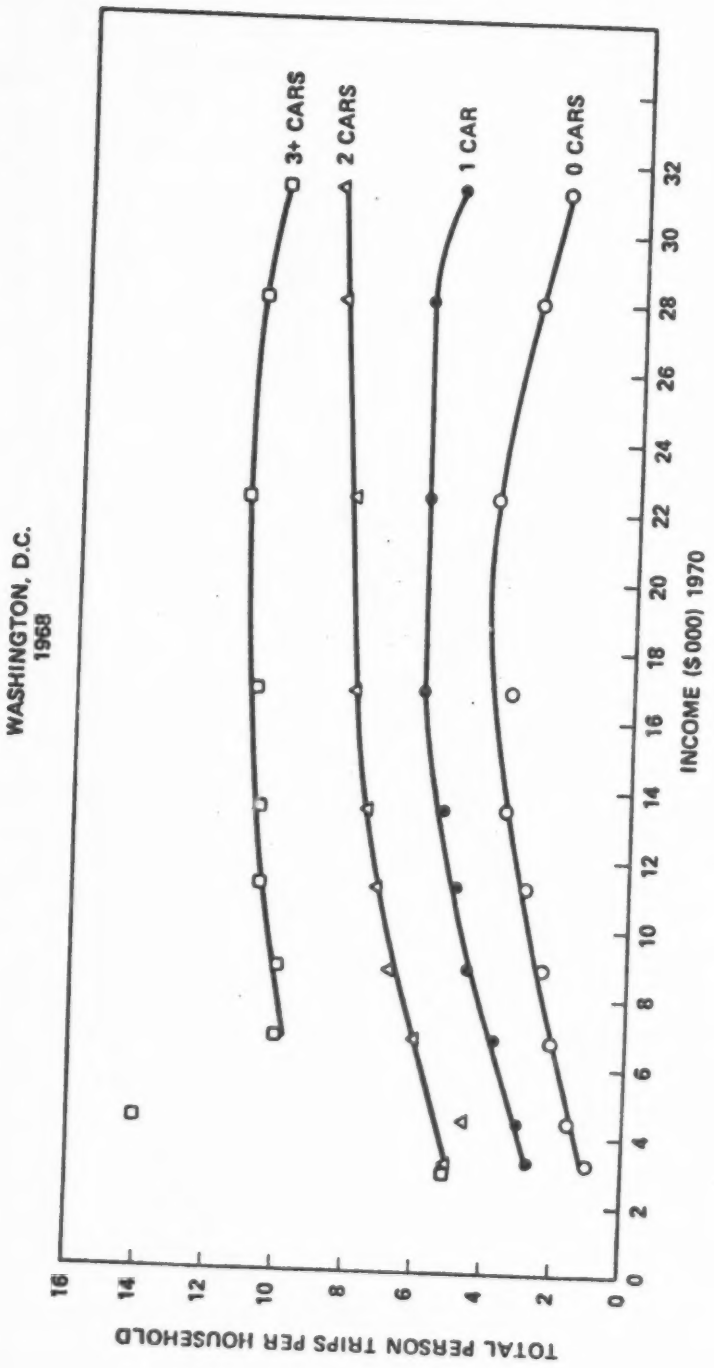
CURVE 2

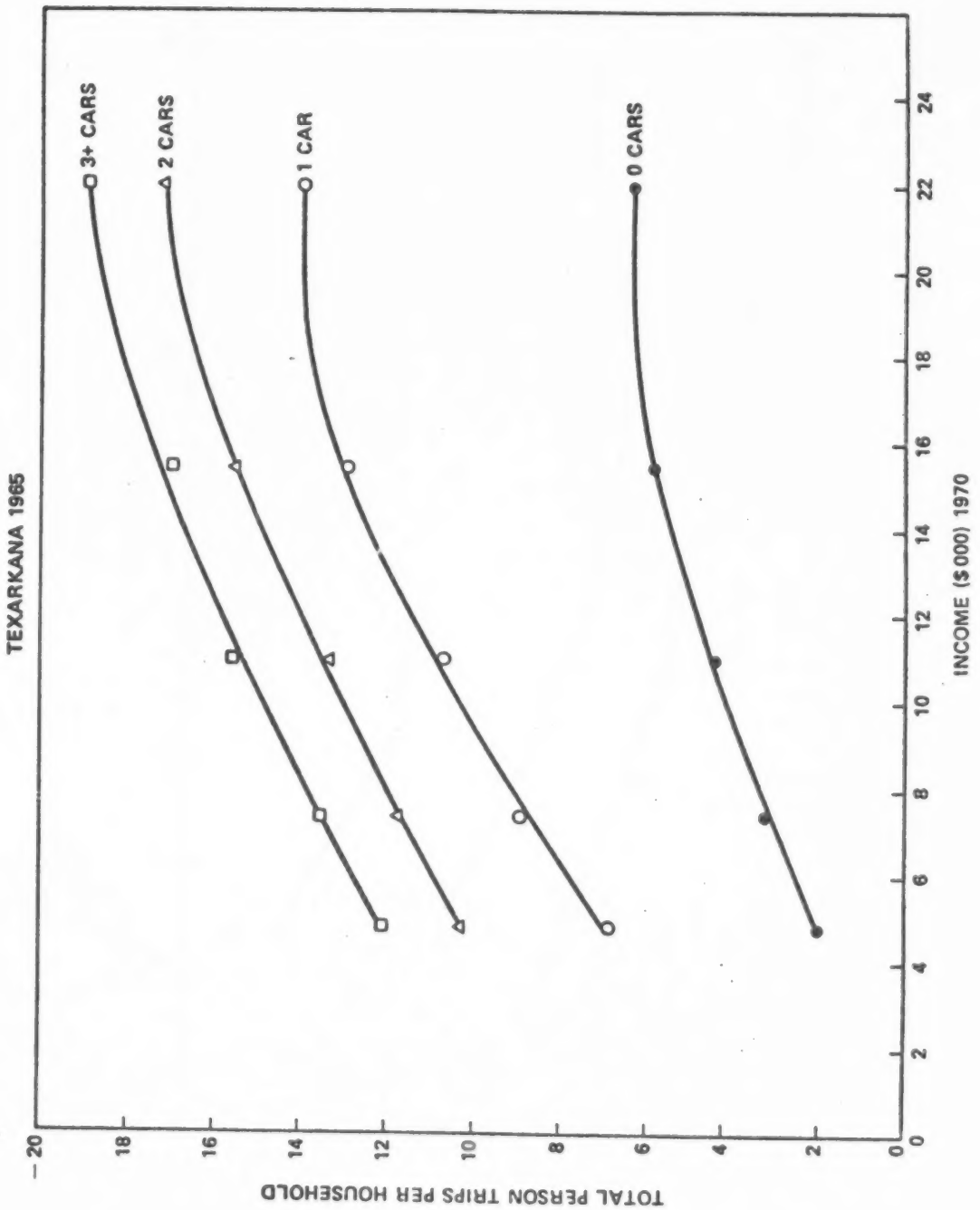
TOTAL PERSON TRIP
GENERATION

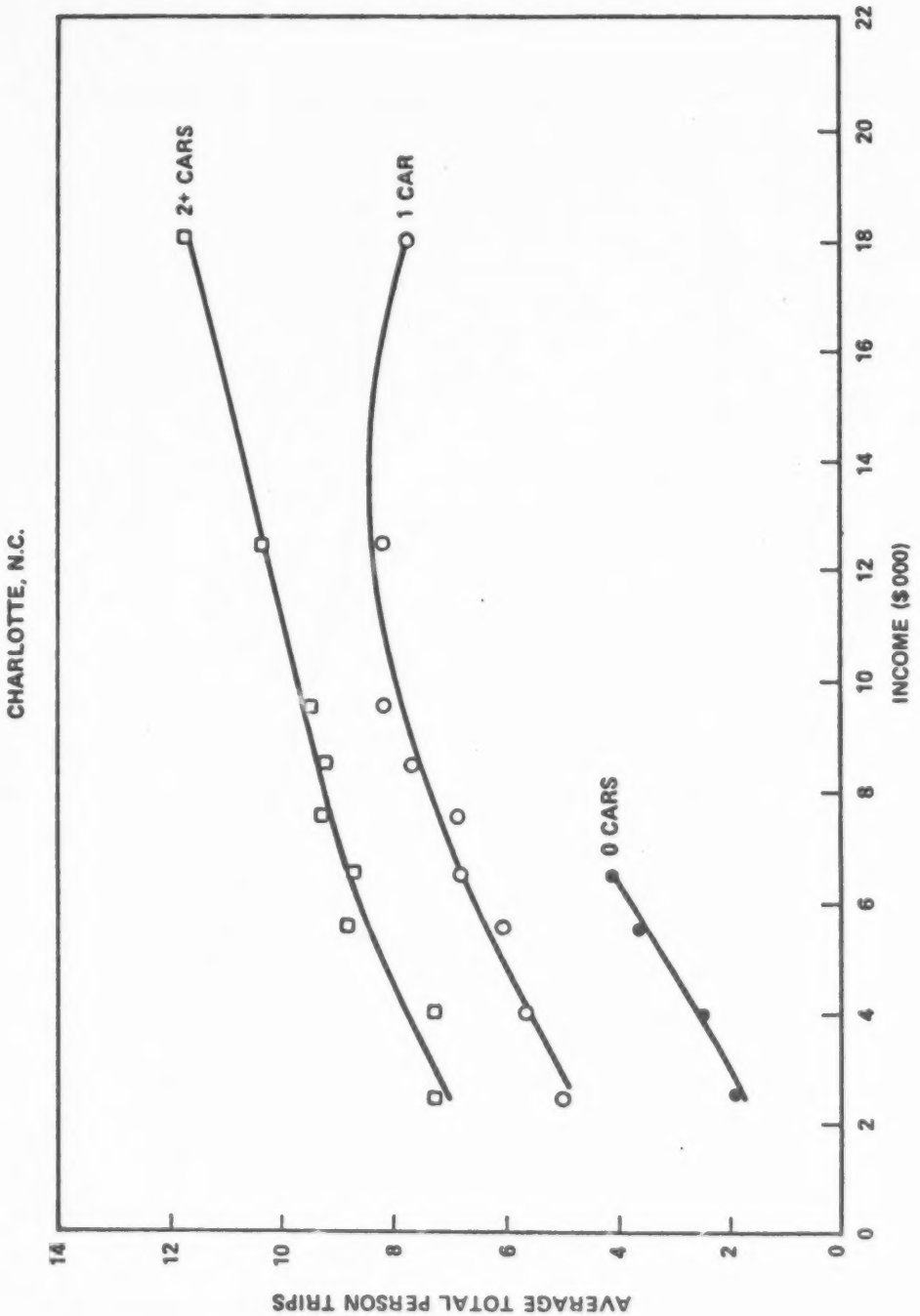


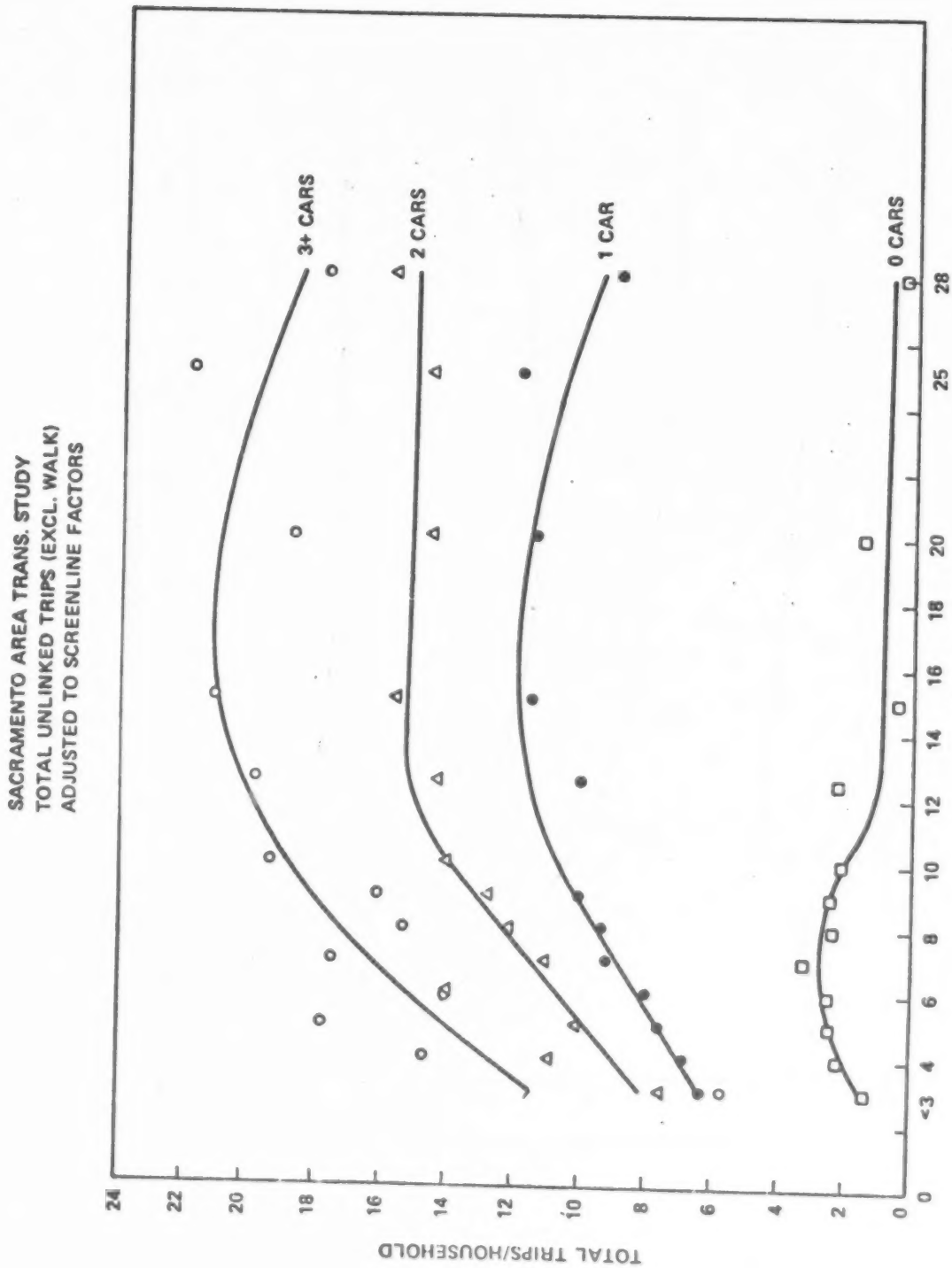
1968 HOUSEHOLD INCOME ($000)

CURVE 2

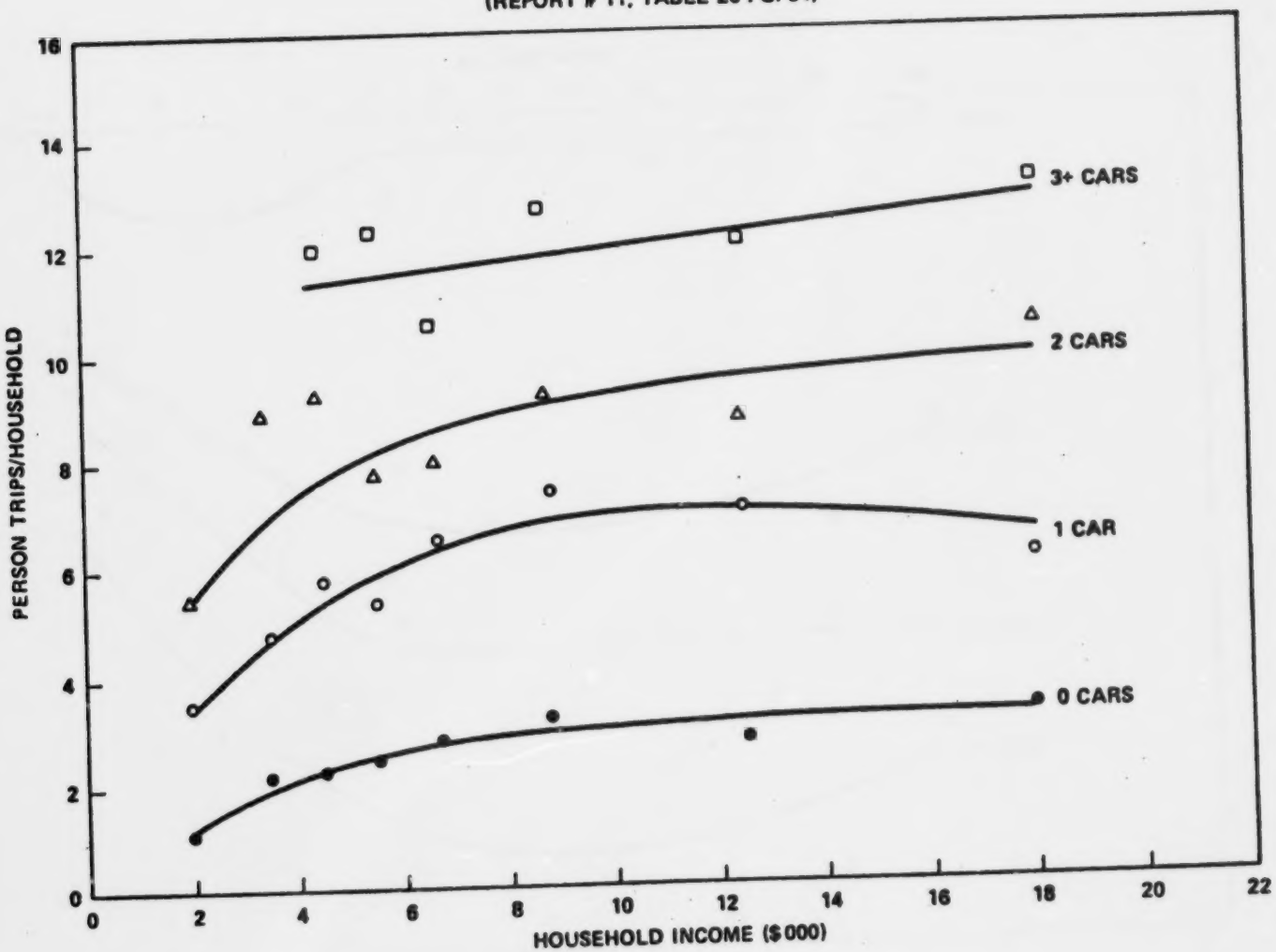

WASHINGTON, D.C.
1968
3+ CARS
2 CARS
1 CAR
0 CARS
TOTAL PERSON TRIPS PER HOUSEHOLD
INCOME ($000) 1970
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32

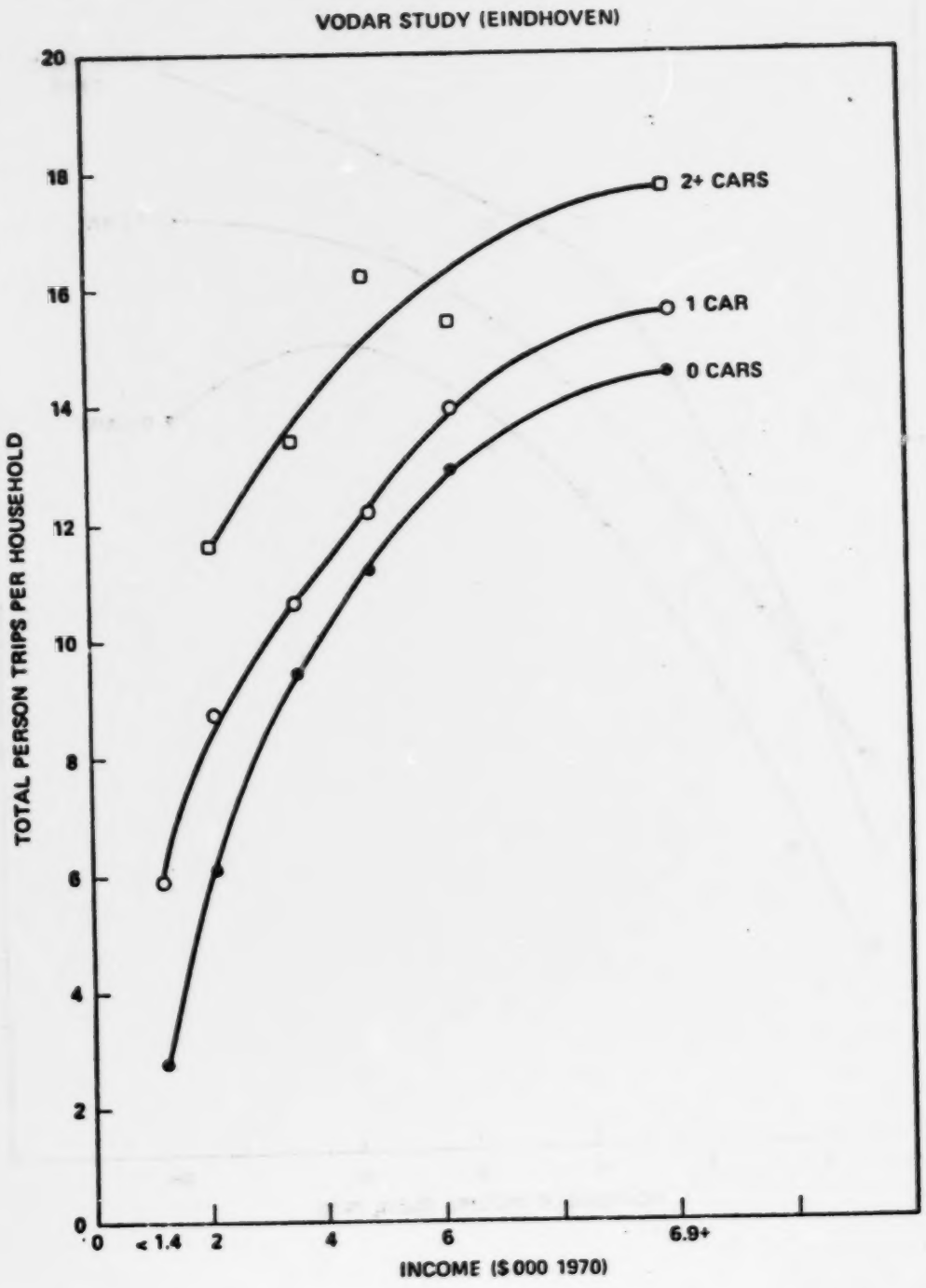

TEXARKANA 1965
3+ CARS
2 CARS
1 CAR
0 CARS
TOTAL PERSON TRIPS PER HOUSEHOLD
INCOME ($000) 1970
0
2
4
6
8
10
12
14
16
18
20
22
24

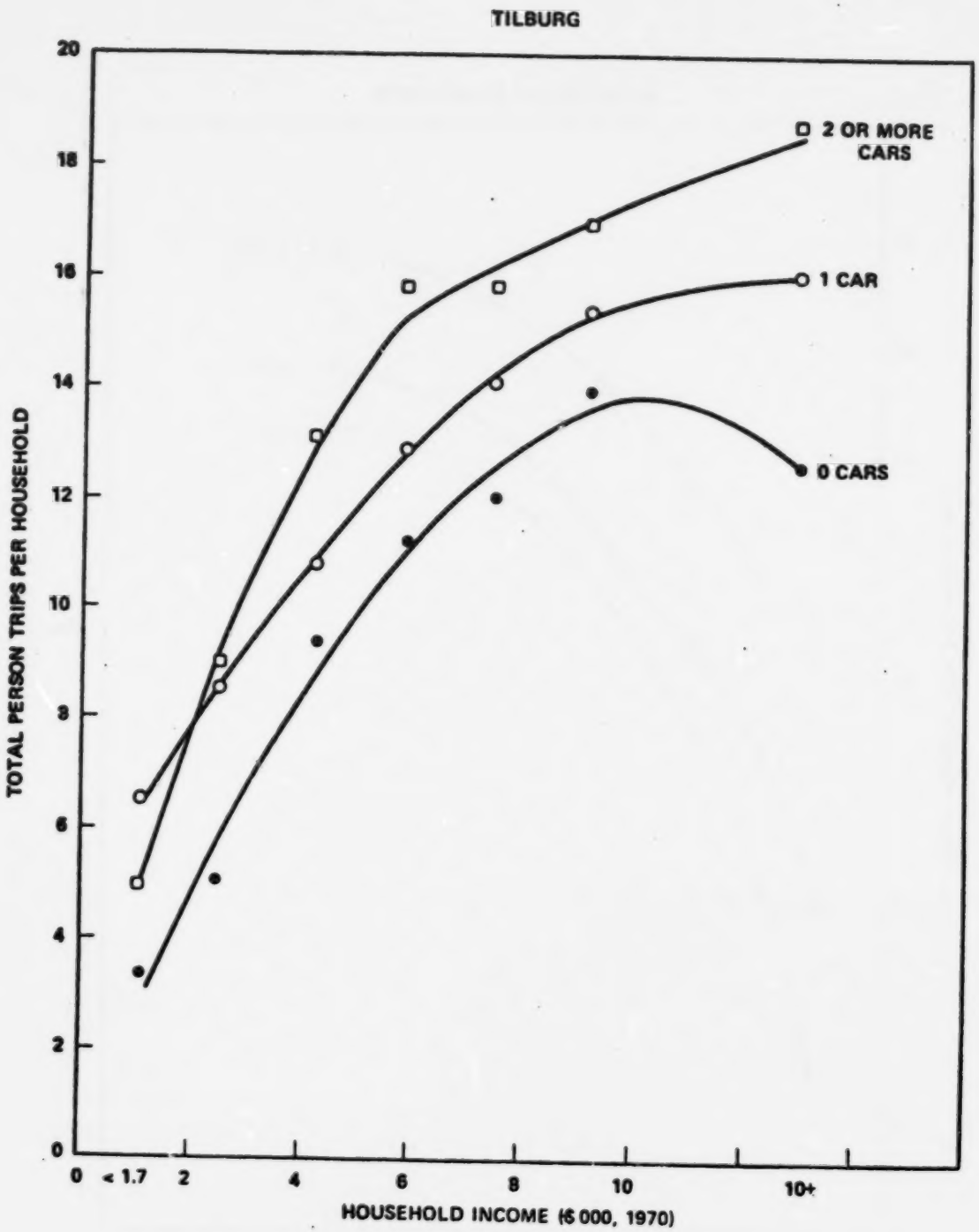

CHARLOTTE, N.C.
2+ CARS
1 CAR
0 CARS
AVERAGE TOTAL PERSON TRIPS
INCOME ($000)
0
2
4
6
8
10
12
14
16
18
20
22

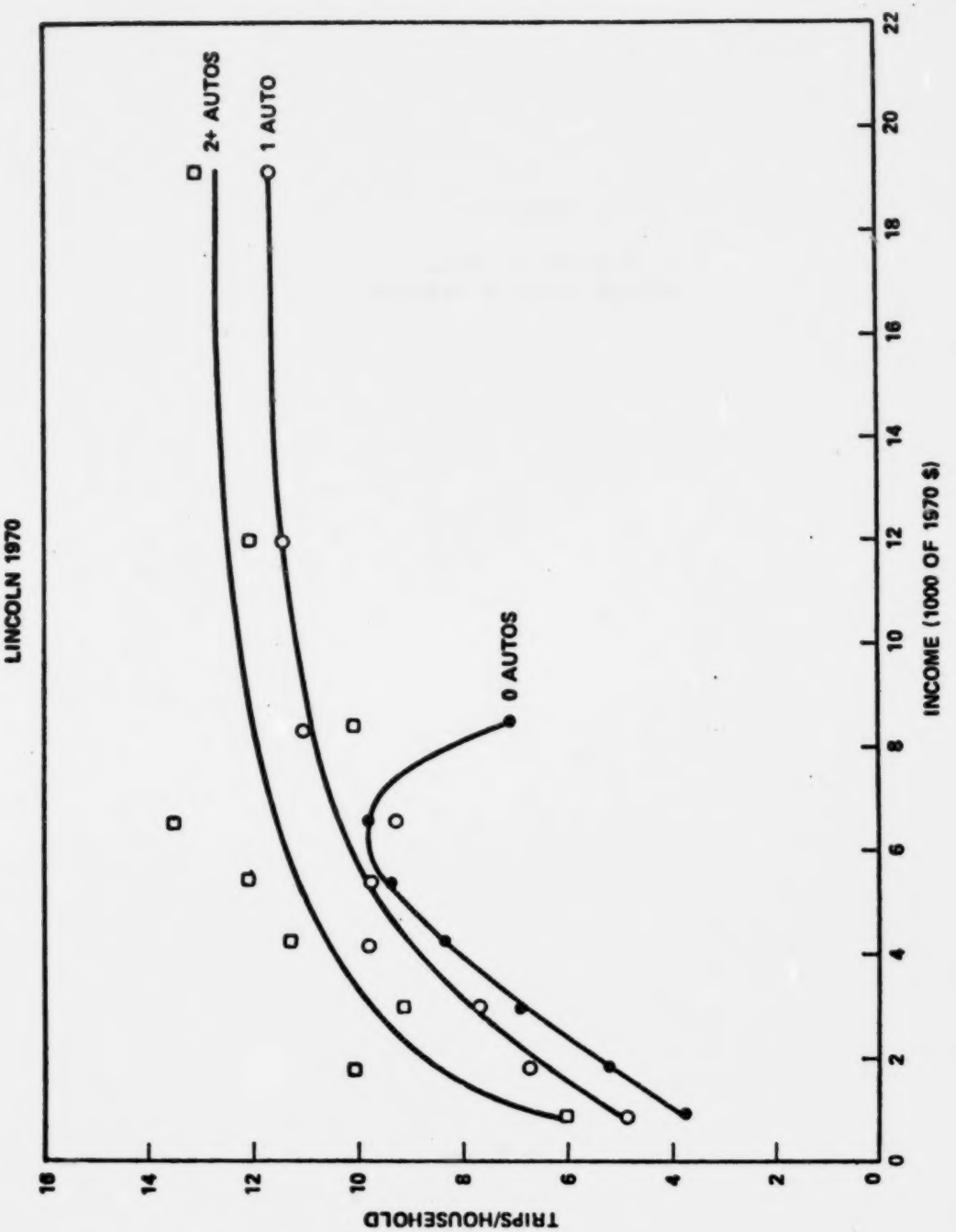

SACRAMENTO AREA TRANS. STUDY
TOTAL UNLINKED TRIPS (EXCL. WALK)
ADJUSTED TO SCREENLINE FACTORS
TOTAL TRIPS/HOUSEHOLD
INCOME ($000)
3+ CARS
2 CARS
1 CAR
0 CARS
0
2
4
6
8
10
12
14
16
18
20
22
24
<3
4
6
8
10
12
14
16
18
20
25
28

NATIONWIDE PERSONAL TRANSPORTATION SURVEY
(1969-70)
(REPORT # 11, TABLE 26 PG. 51)



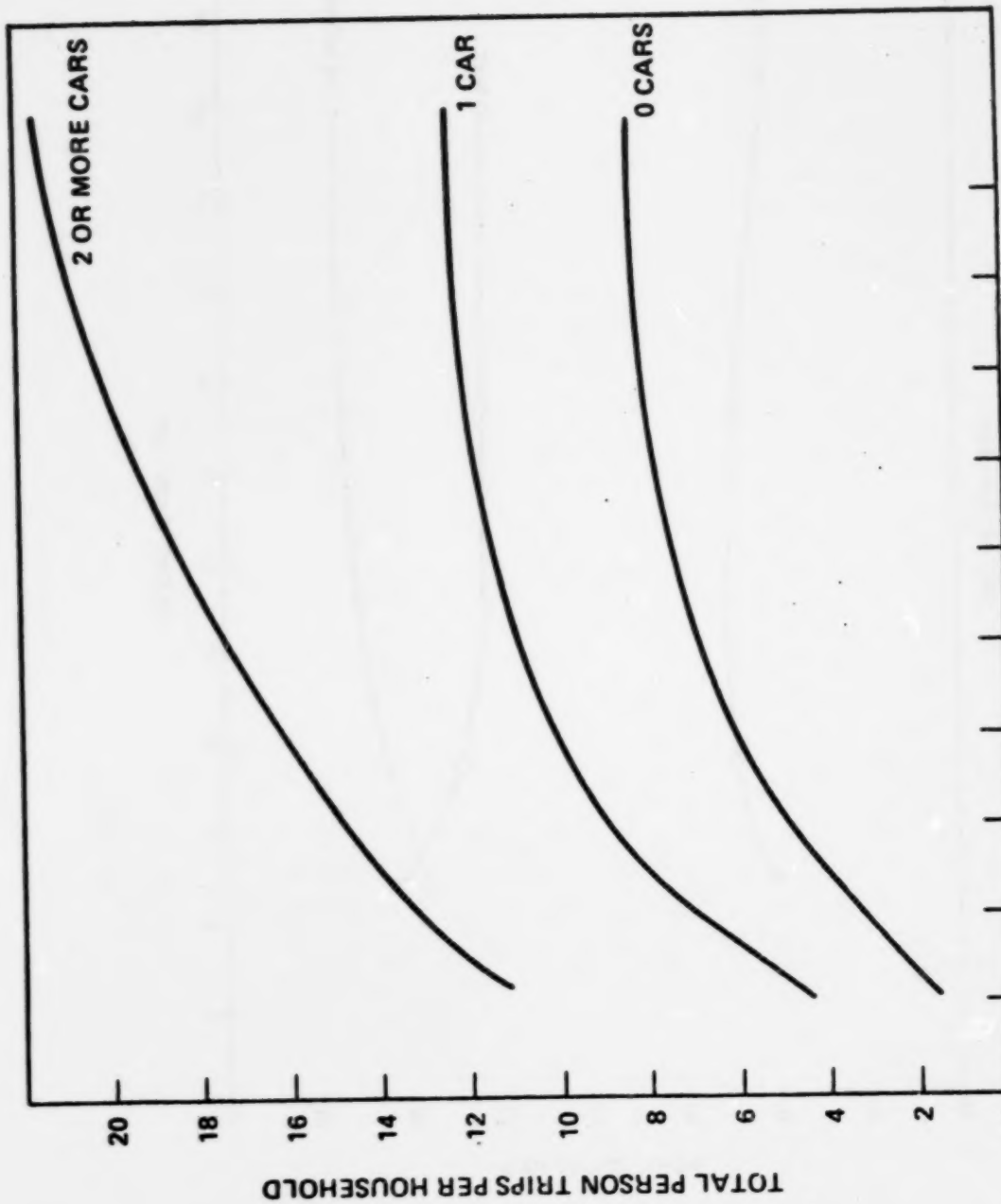

VODAR STUDY (EINDHOVEN)
TOTAL PERSON TRIPS PER HOUSEHOLD
20
18
16
14
12
10
8
6
4
2
0
2+ CARS
1 CAR
0 CARS
0
< 1.4
2
4
6
6.9+
INCOME ($ 000 1970)


TILBURG
TOTAL PERSON TRIPS PER HOUSEHOLD
HOUSEHOLD INCOME (f 000, 1970)
2 OR MORE CARS
1 CAR
0 CARS
0
2
4
6
8
10
12
14
16
18
20
0
< 1.7
2
4
6
8
10
10+

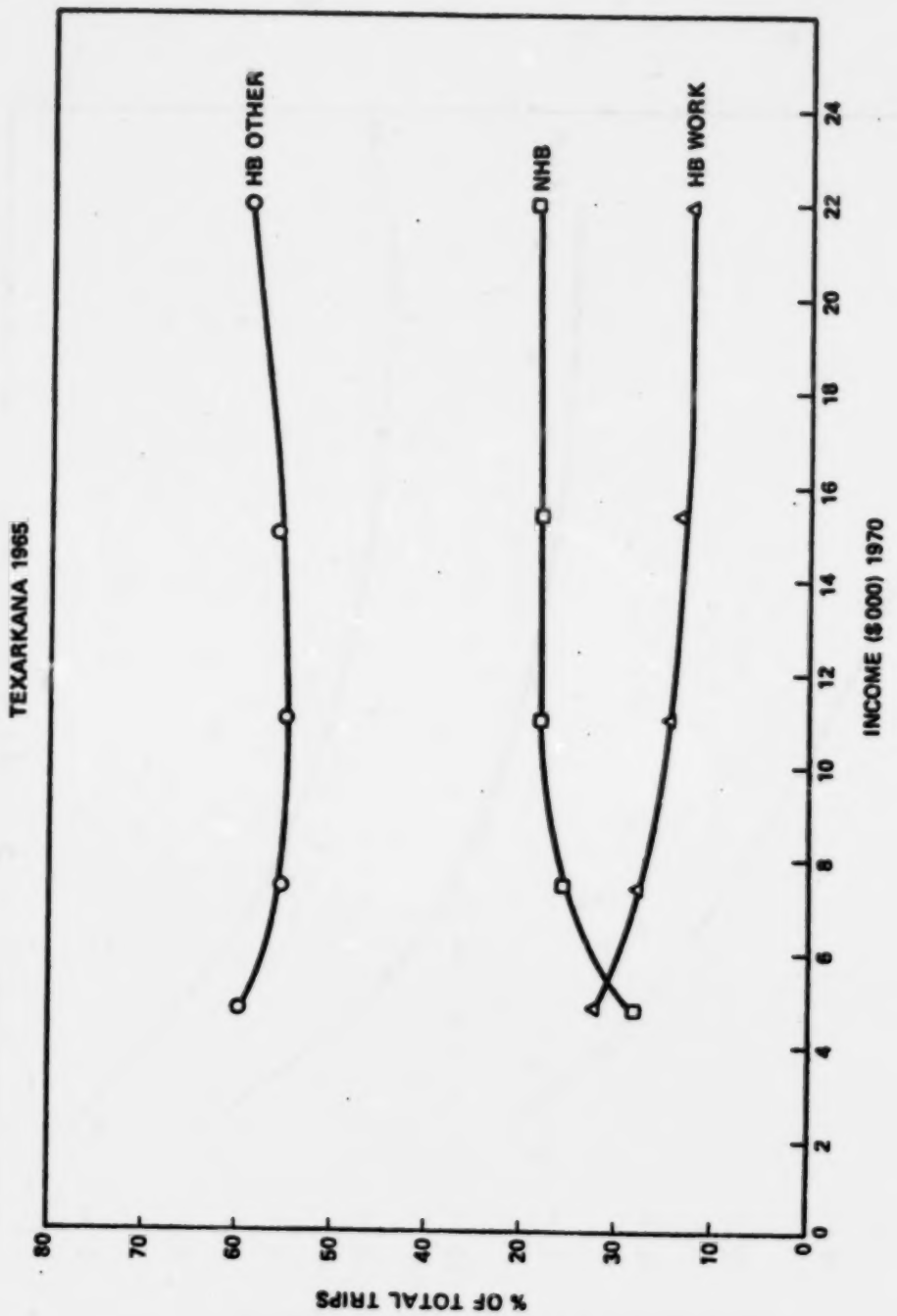

LINCOLN 1970
2+ AUTOS
1 AUTO
0 AUTOS
TRIPS/HOUSEHOLD
INCOME (1000 OF 1970 $)
0
2
4
6
8
10
12
14
16
18
20
22

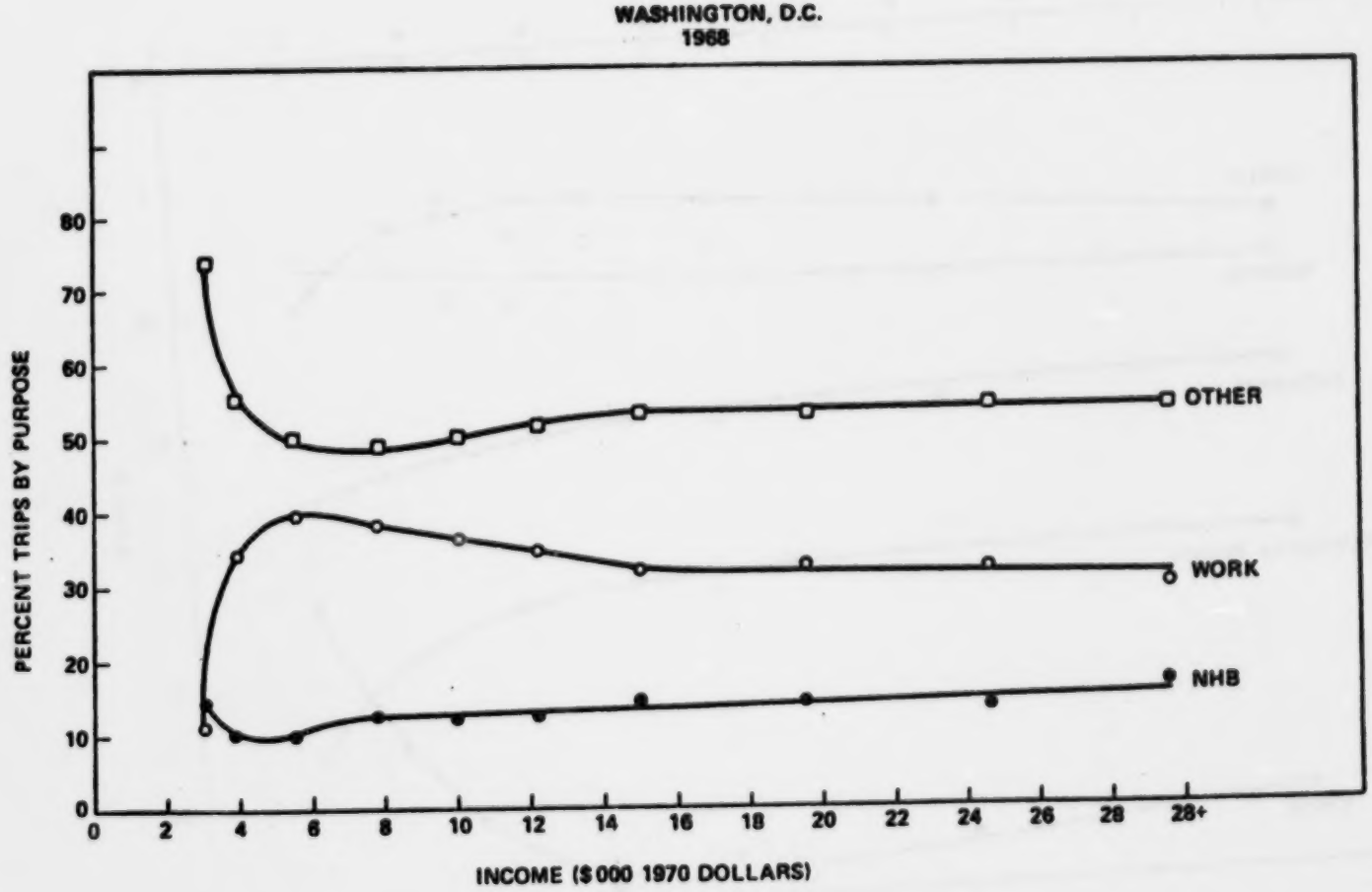
CURVE 3

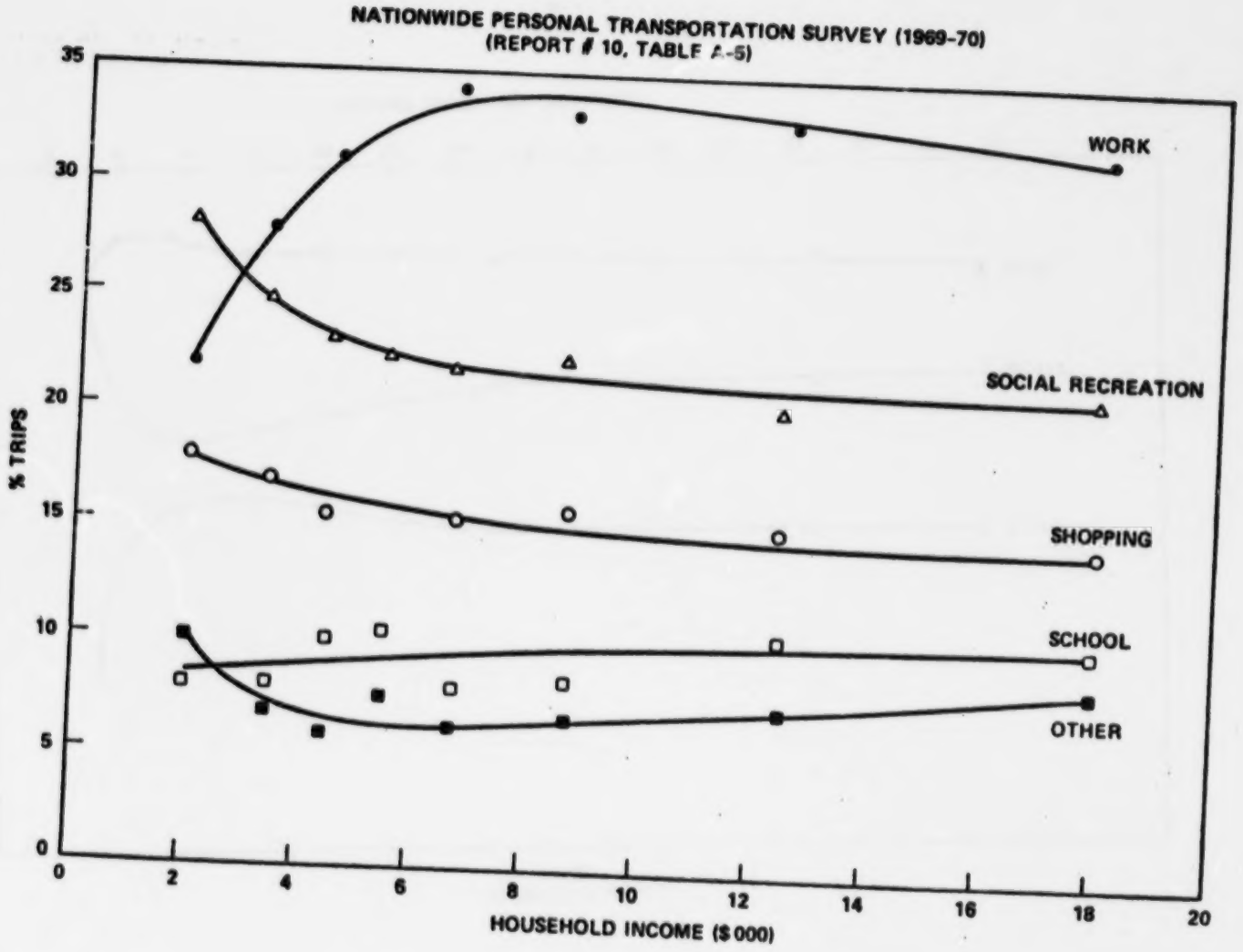
PERCENT OF TOTAL
PERSON TRIPS BY PURPOSE

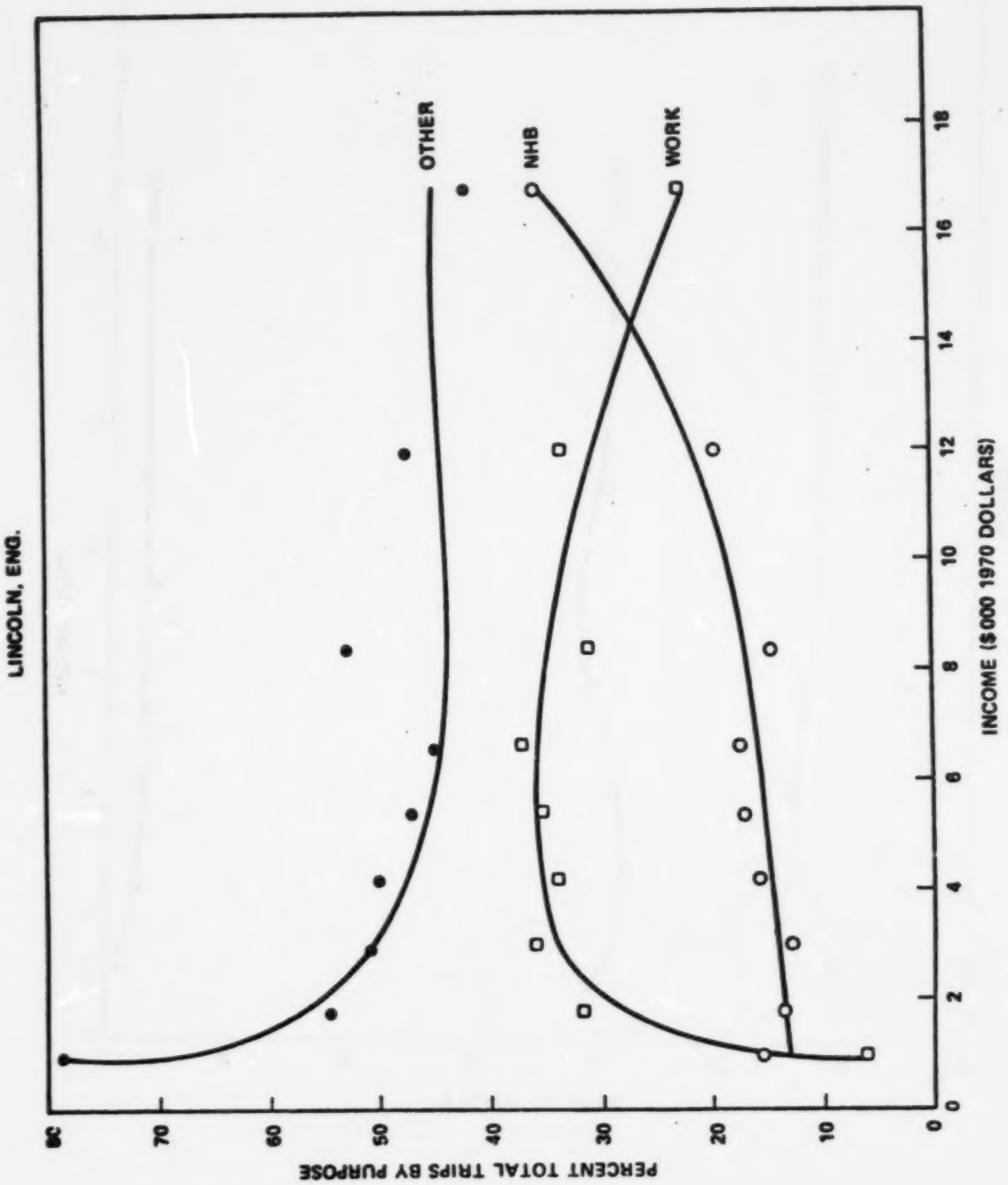

2 OR MORE CARS
1 CAR
0 CARS
TOTAL PERSON TRIPS PER HOUSEHOLD
0
2
4
6
8
10
12
14
16
18
20
1968 HOUSEHOLD INCOME ($000)

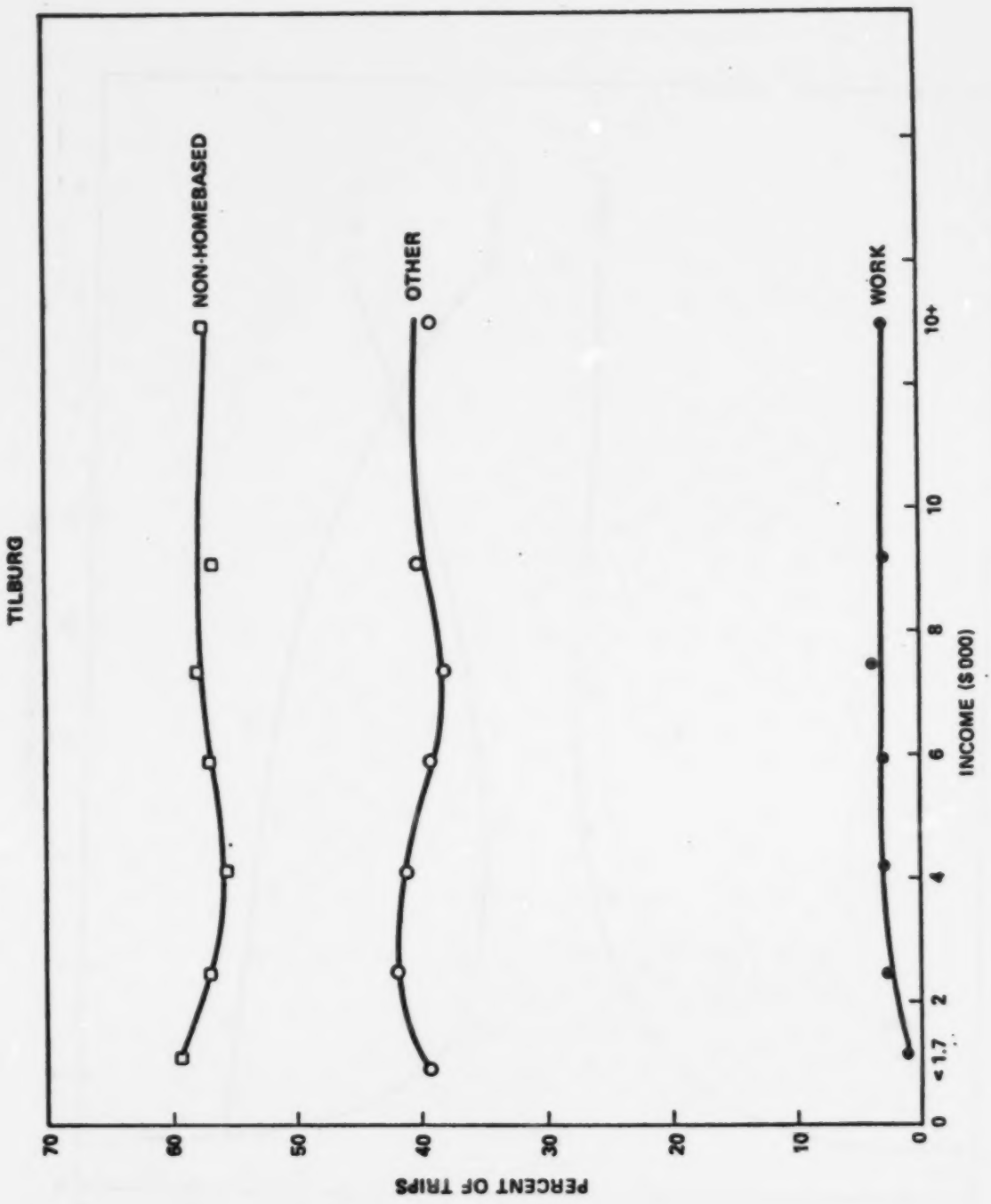
CURVE 3


TEXARKANA 1965
HB OTHER
NHB
HB WORK
% OF TOTAL TRIPS
INCOME ($000) 1970
80
70
60
50
40
20
30
10
0
2
4
6
8
10
12
14
16
18
20
22
24


WASHINGTON, D.C.
1968
PERCENT TRIPS BY PURPOSE
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
28+
INCOME ($000 1970 DOLLARS)
OTHER
WORK
NHB

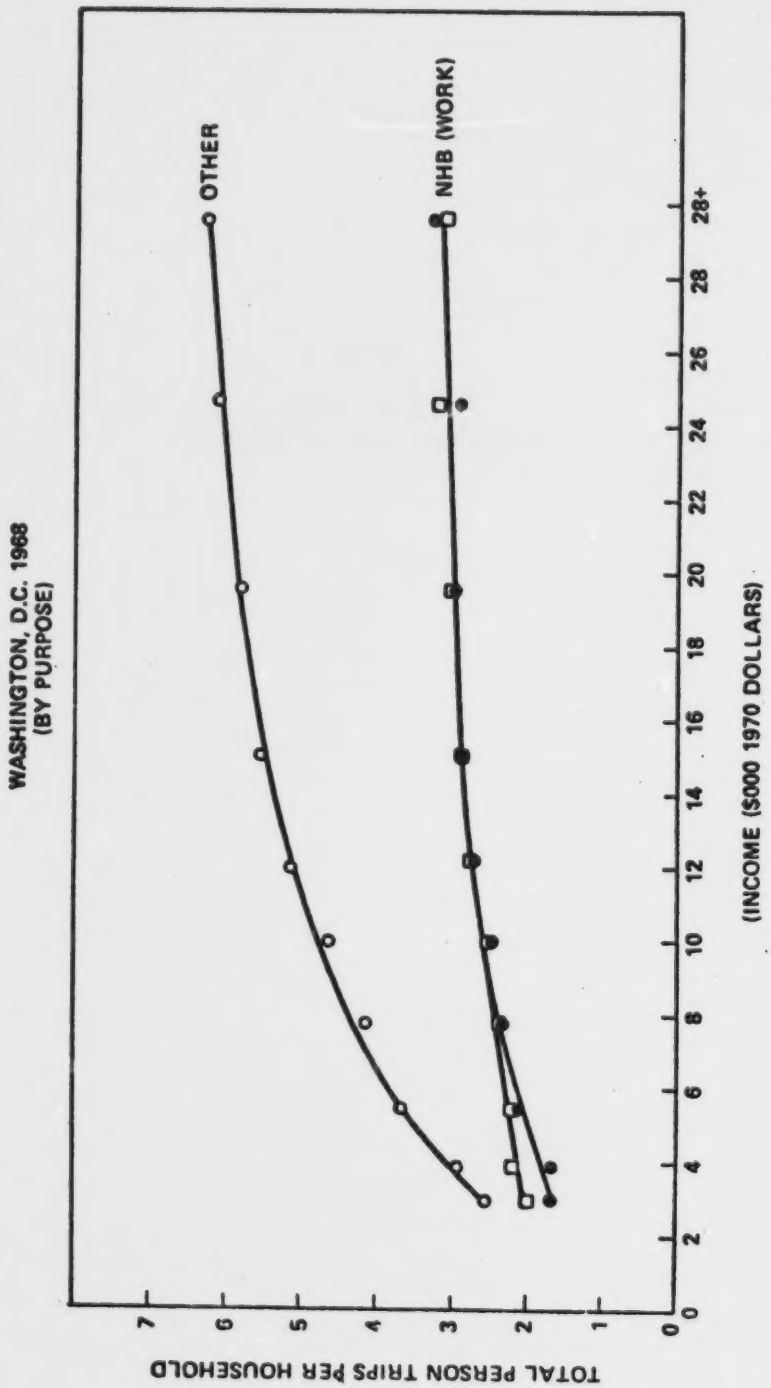

NATIONWIDE PERSONAL TRANSPORTATION SURVEY (1969-70)
(REPORT # 10, TABLE A-5)
% TRIPS
HOUSEHOLD INCOME ($000)
WORK
SOCIAL RECREATION
SHOPPING
SCHOOL
OTHER
0
5
10
15
20
25
30
35
0
2
4
6
8
10
12
14
16
18
20

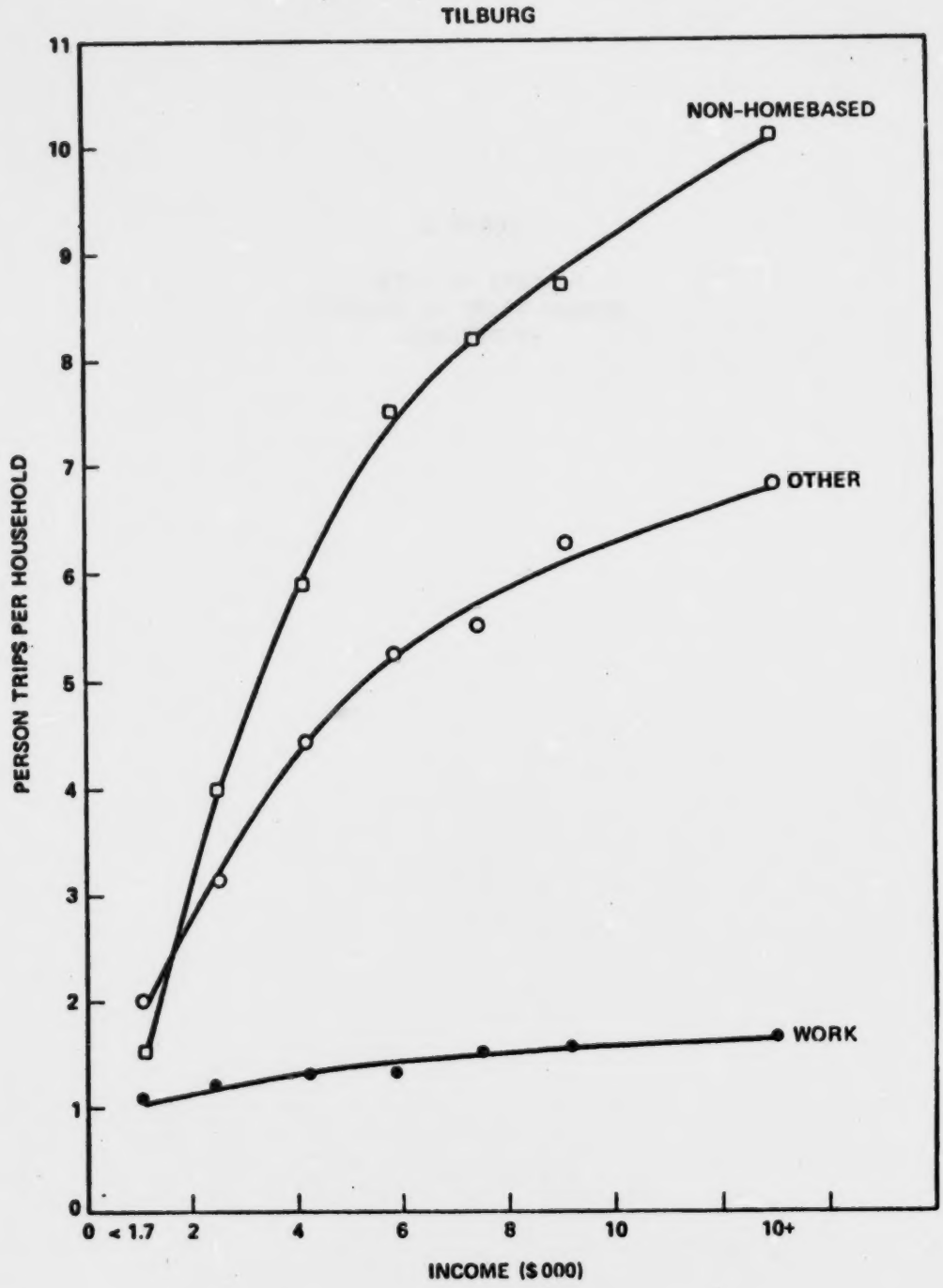

LINCOLN, ENG.
OTHER
NHB
WORK
PERCENT TOTAL TRIPS BY PURPOSE
INCOME ($000 1970 DOLLARS)
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18


TILBURG
NON-HOMEBASED
OTHER
WORK
PERCENT OF TRIPS
INCOME ($ 000)
0
< 1.7
2
4
6
8
10
10+
10
20
30
40
50
60
70

CURVE 3a

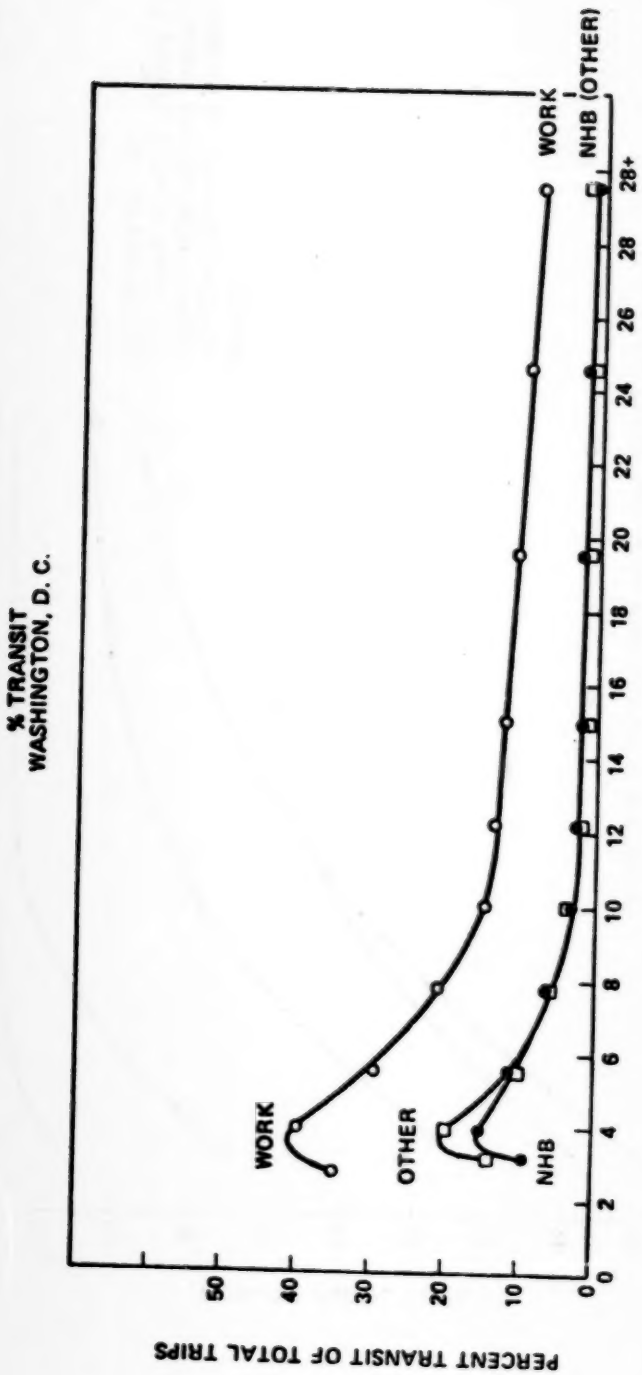
PERSON TRIPS
PER HOUSEHOLD BY PURPOSE

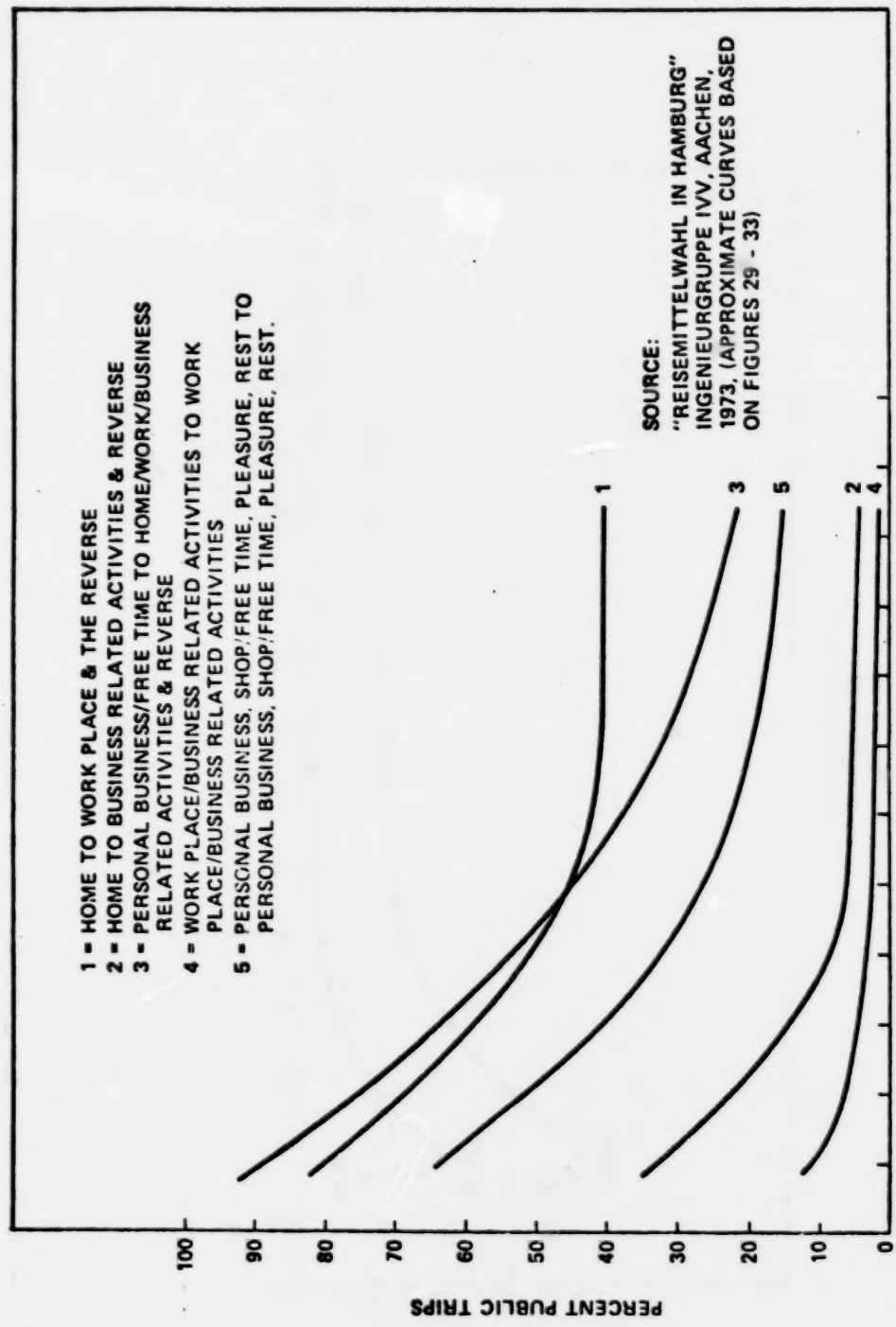

WASHINGTON, D.C. 1968
(BY PURPOSE)
OTHER
NHB (WORK)
TOTAL PERSON TRIPS PER HOUSEHOLD
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
28+
(INCOME ($000 1970 DOLLARS)


TILBURG
NON-HOMEBASED
OTHER
WORK
PERSON TRIPS PER HOUSEHOLD
INCOME ($ 000)
0
1
2
3
4
5
6
7
8
9
10
11
0
< 1.7
2
4
6
8
10
10+

CURVE 4

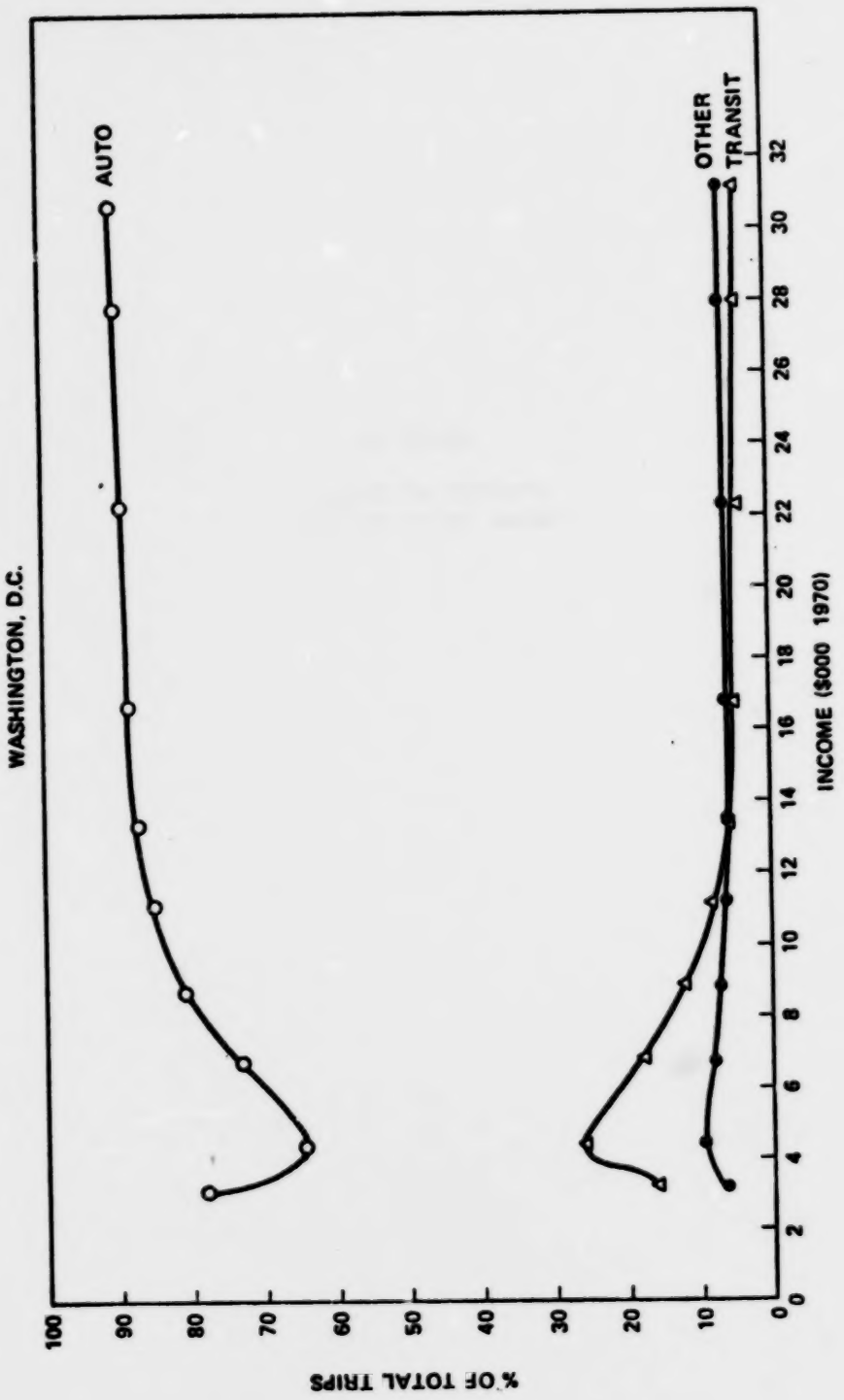
PERCENT OF TOTAL
PERSON TRIPS BY TRANSIT
BY PURPOSE

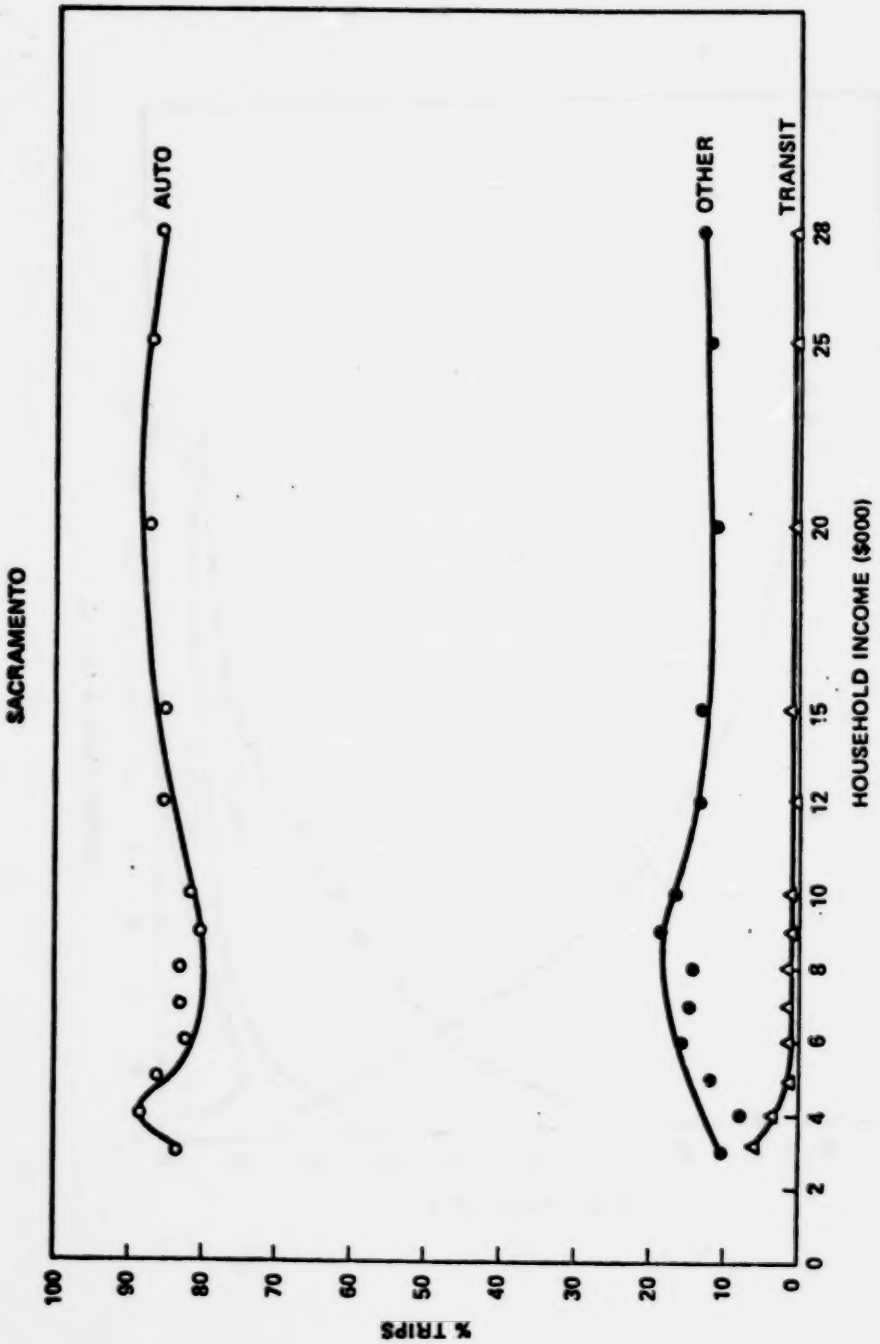

% TRANSIT
WASHINGTON, D. C.
PERCENT TRANSIT OF TOTAL TRIPS
WORK
OTHER
NHB
WORK
NHB (OTHER)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
28+
0
10
20
30
40
50

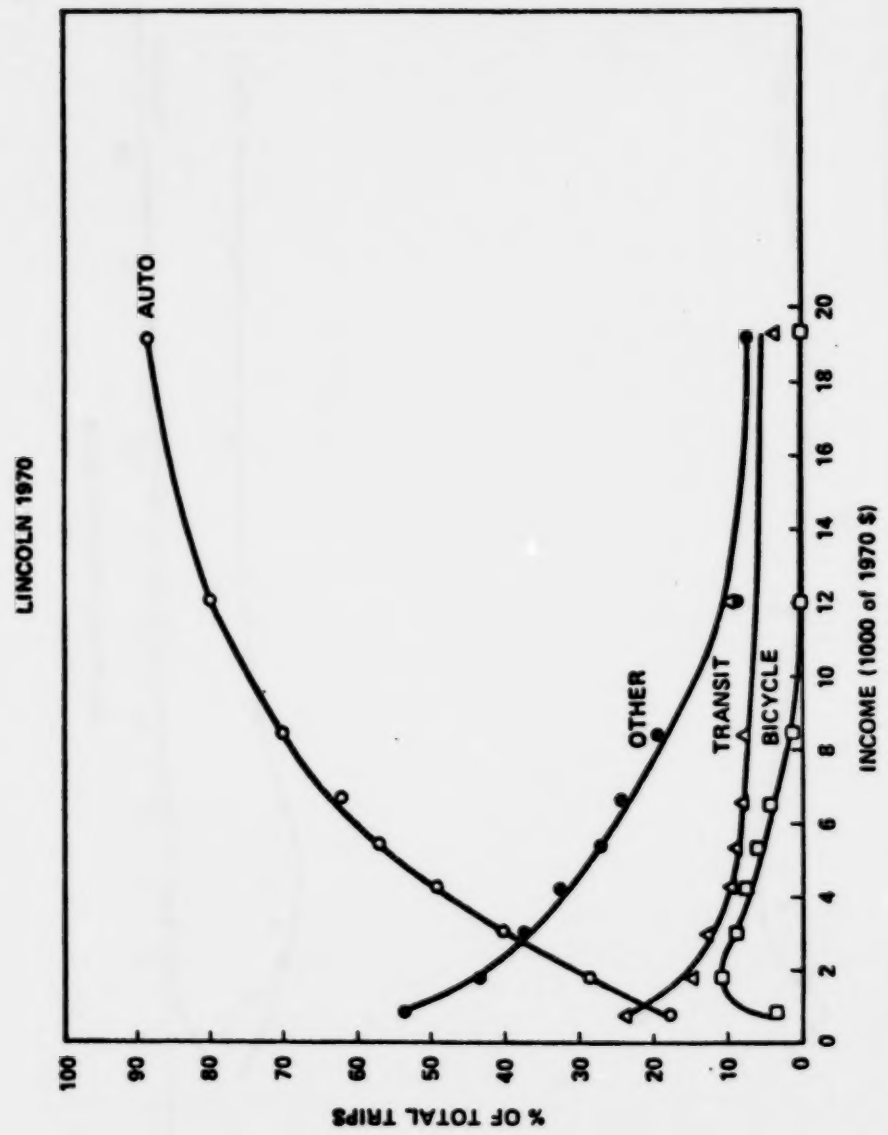

1 = HOME TO WORK PLACE & THE REVERSE
2 = HOME TO BUSINESS RELATED ACTIVITIES & REVERSE
3 = PERSONAL BUSINESS/FREE TIME TO HOME/WORK/BUSINESS RELATED ACTIVITIES & REVERSE
4 = WORK PLACE/BUSINESS RELATED ACTIVITIES TO WORK PLACE/BUSINESS RELATED ACTIVITIES
5 = PERSONAL BUSINESS, SHOP/FREE TIME, PLEASURE, REST TO PERSONAL BUSINESS, SHOP/FREE TIME, PLEASURE, REST.
SOURCE:
"REISEMITTELWAHL IN HAMBURG" INGENIEURGRUPPE IVV, AACHEN, 1973, (APPROXIMATE CURVES BASED ON FIGURES 29 - 33)
PERCENT PUBLIC TRIPS
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12
ANNUAL NET HOUSEHOLD INCOME (000 $ 1970)
1
2
3
4
5

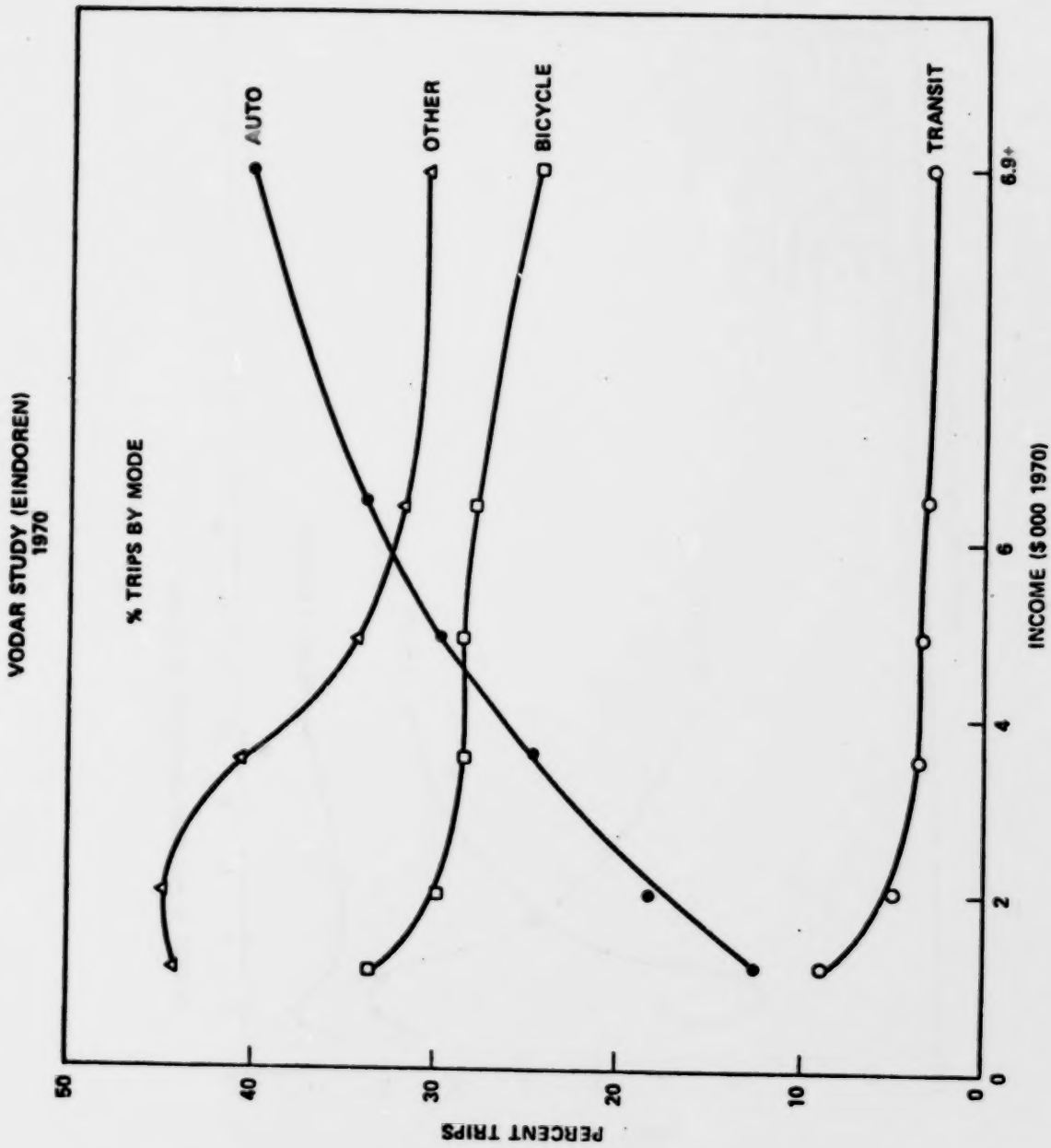
CURVE 4a

PERCENT OF TOTAL
PERSON TRIPS BY MODE

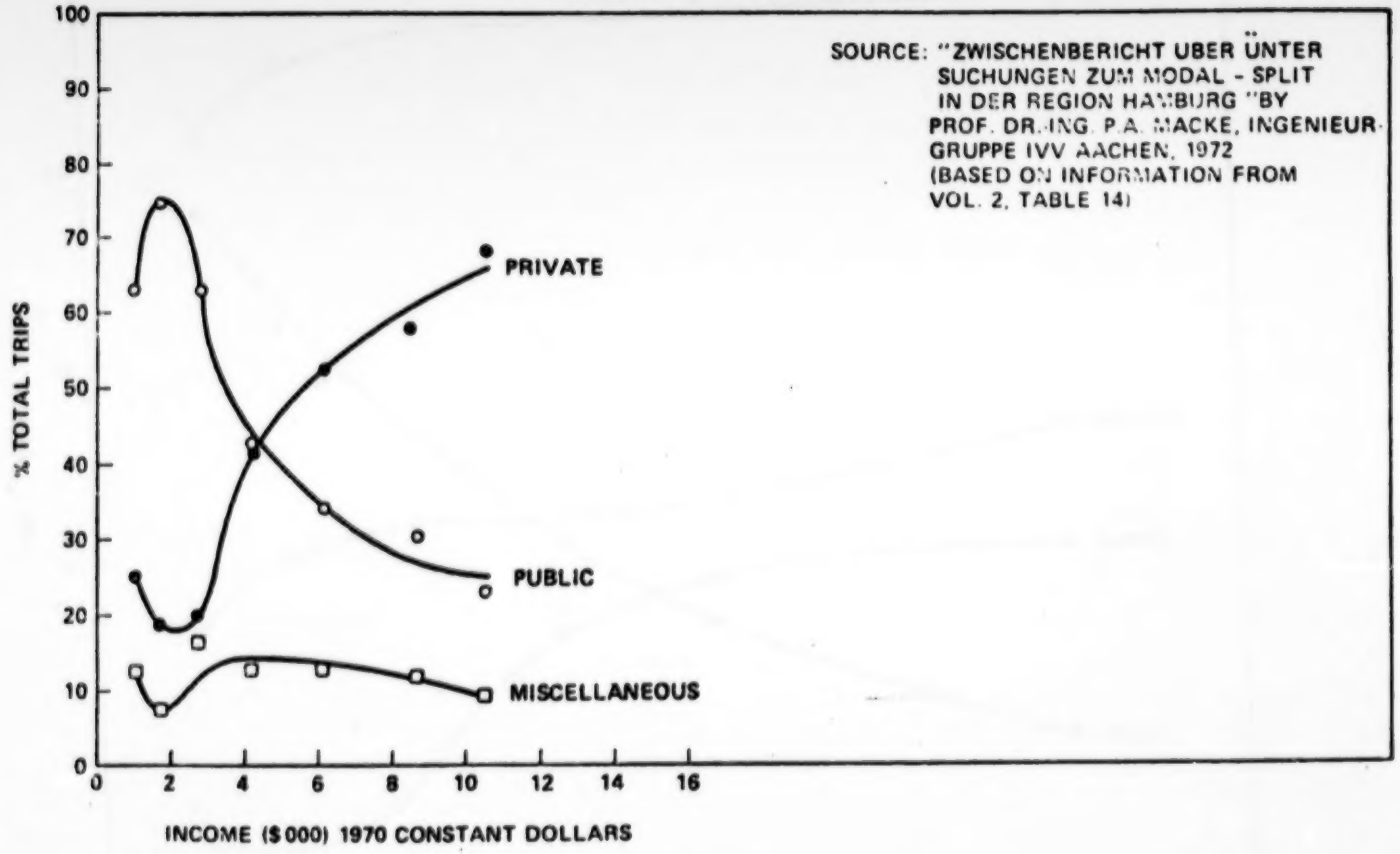

WASHINGTON, D.C.
AUTO
TRANSIT
OTHER
% OF TOTAL TRIPS
INCOME ($000 1970)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32


SACRAMENTO
AUTO
OTHER
TRANSIT
% TRIPS
HOUSEHOLD INCOME ($000)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
15
20
25
28

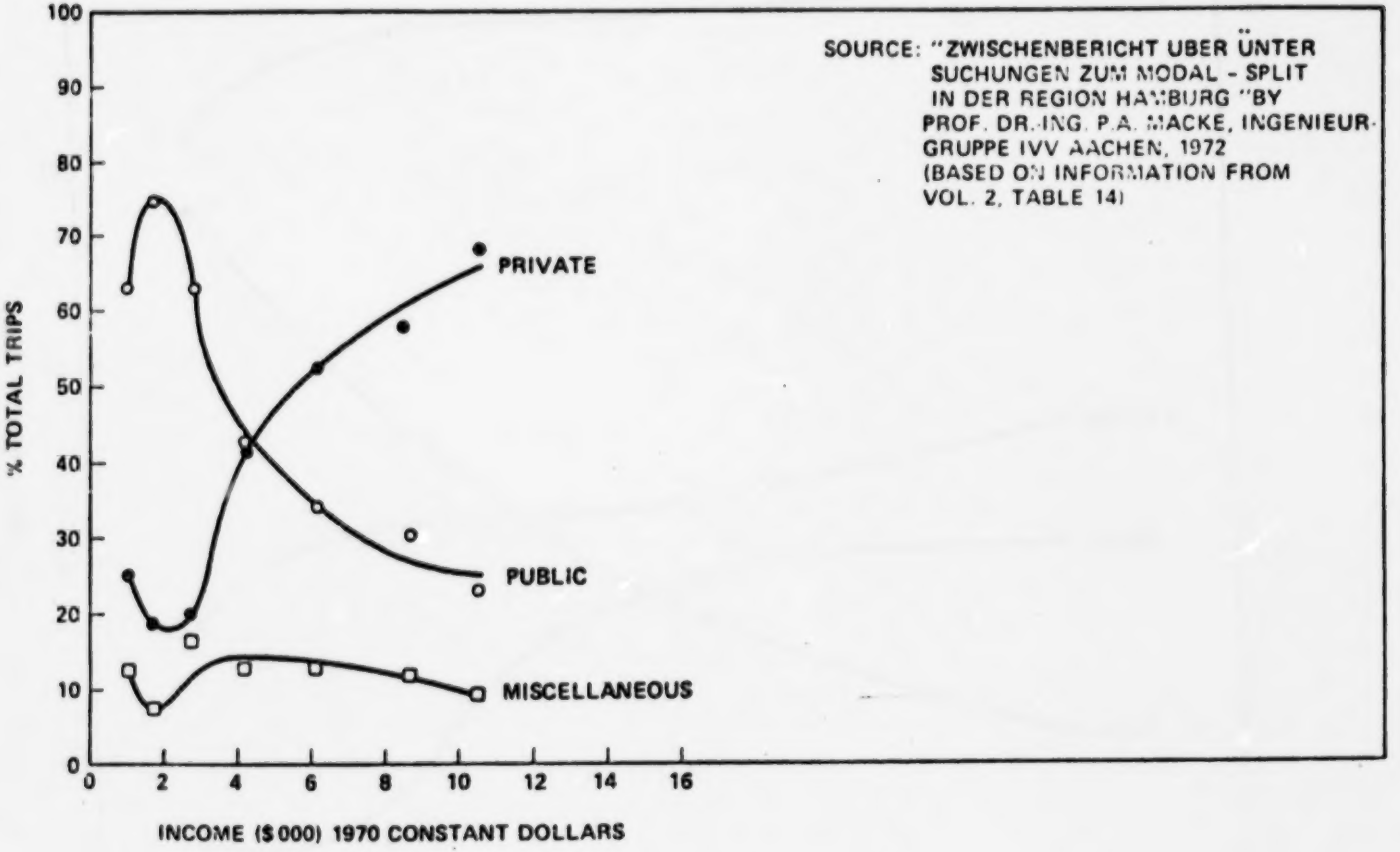

LINCOLN 1970
AUTO
OTHER
TRANSIT
BICYCLE
% OF TOTAL TRIPS
INCOME (1000 of 1970 $)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20


VODAR STUDY (EINDOREN)
1970
% TRIPS BY MODE
AUTO
OTHER
BICYCLE
TRANSIT
PERCENT TRIPS
INCOME ($ 000 1970)
0
10
20
30
40
50
2
4
6
8.9+

HAMBURG, WEST GERMANY, 1972

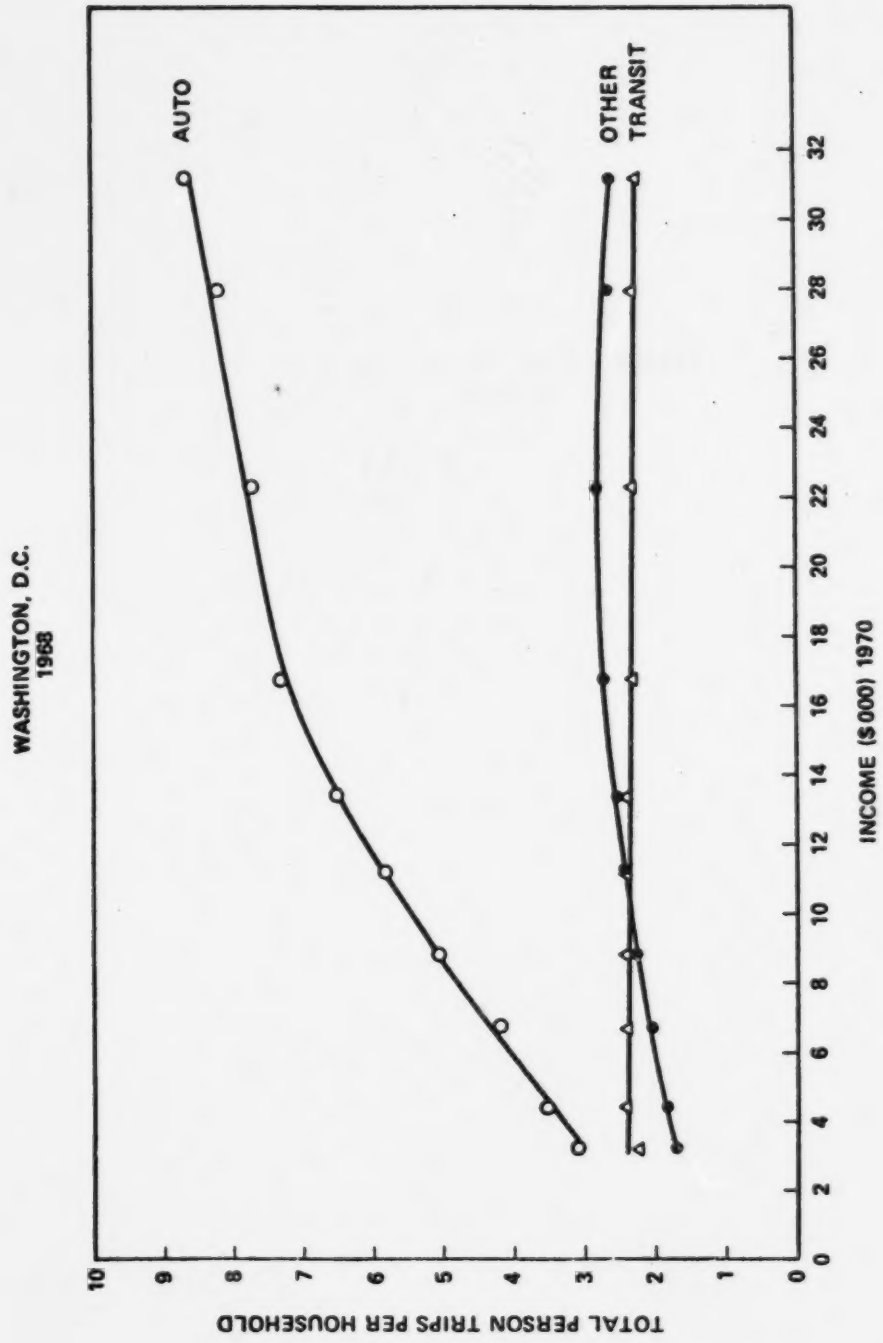


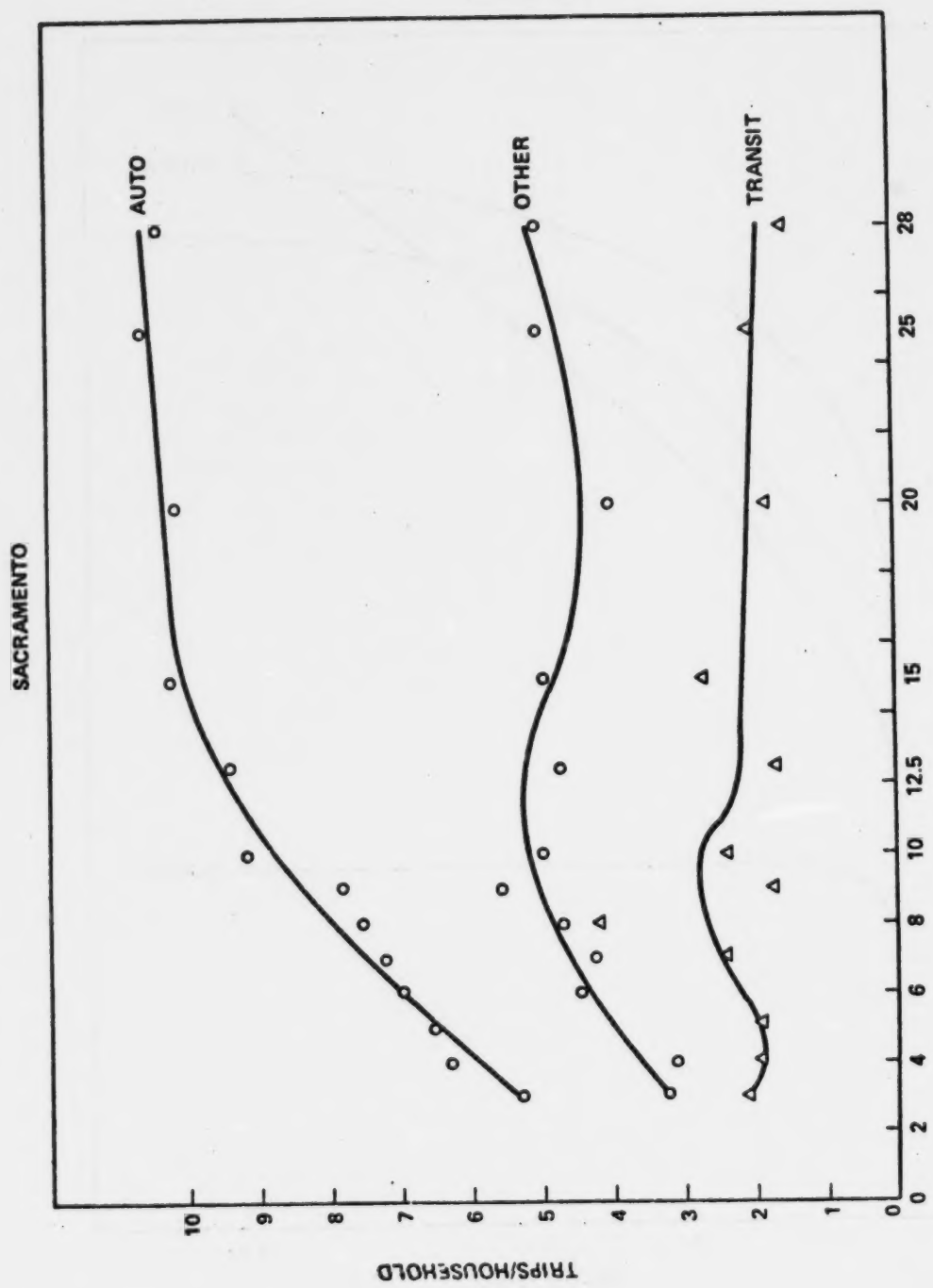
HAMBURG, WEST GERMANY, 1972

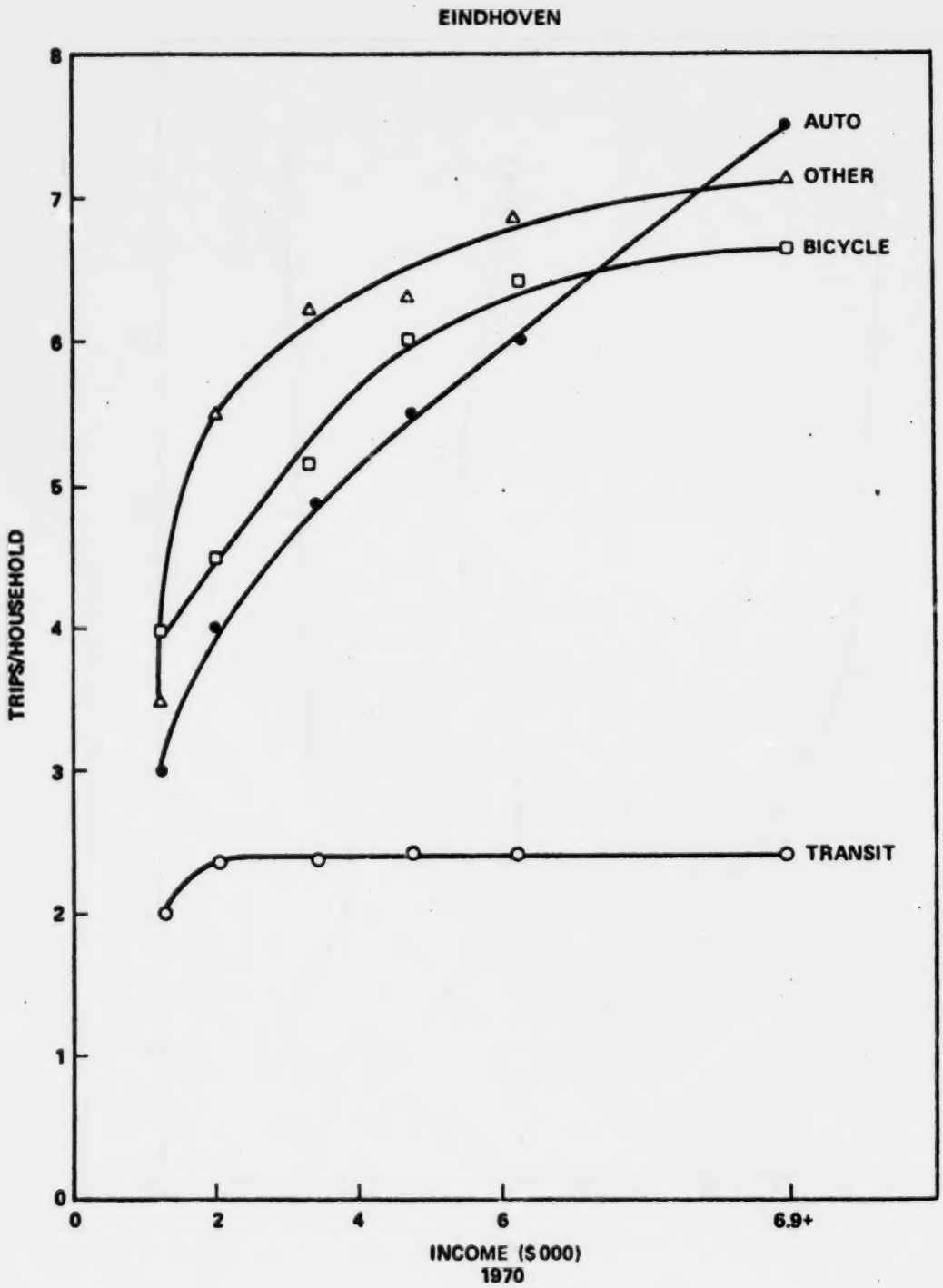


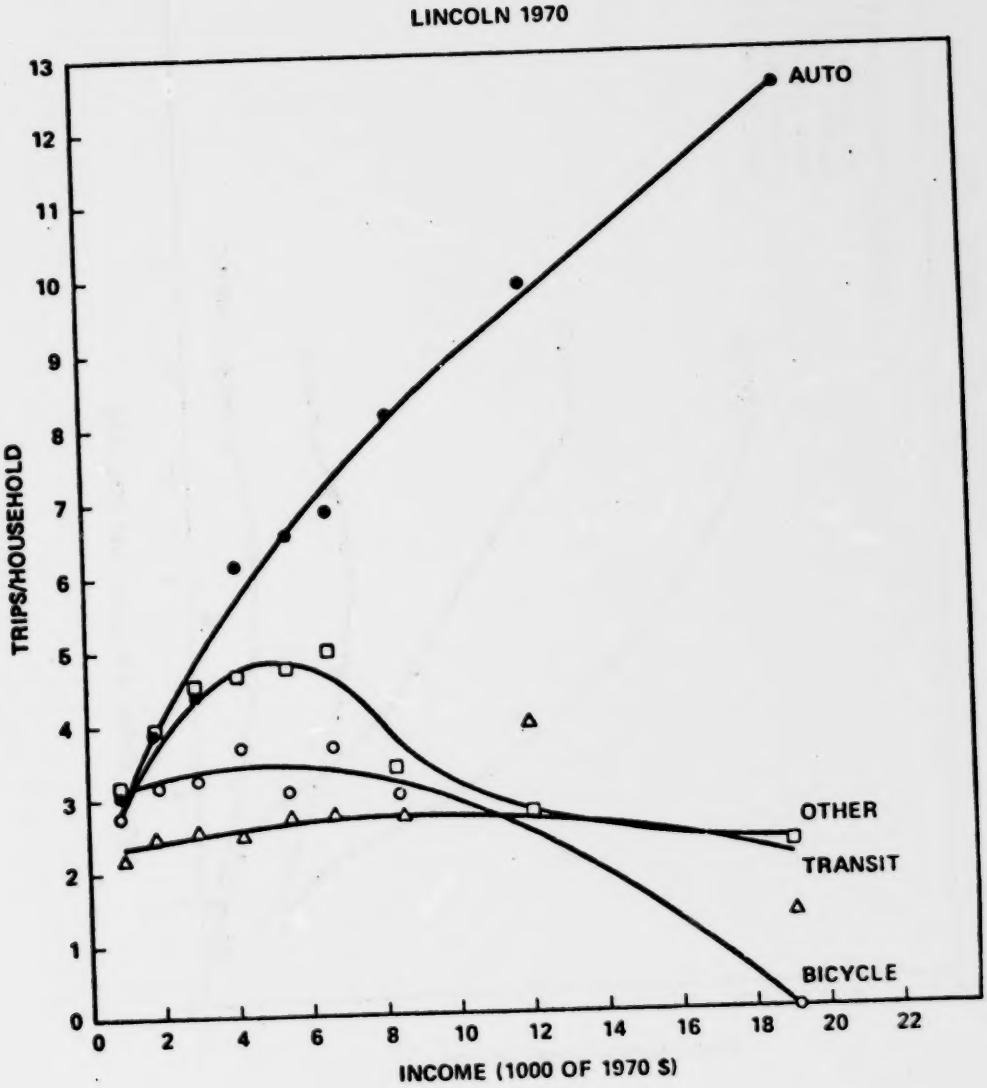
CURVE 4b

PERSON TRIPS PER HOUSEHOLD
BY MODE

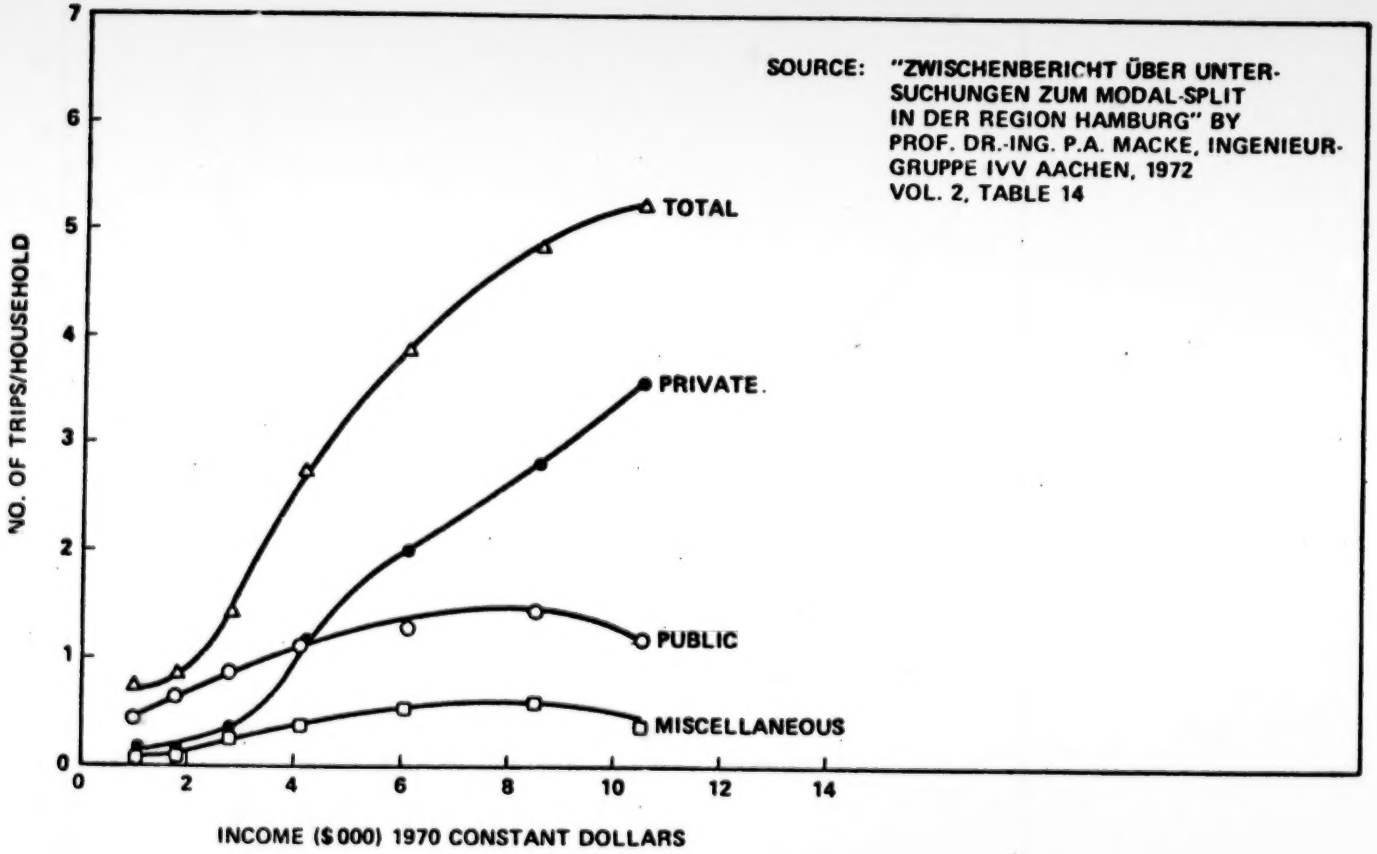

WASHINGTON, D.C.
1968
AUTO
OTHER
TRANSIT
TOTAL PERSON TRIPS PER HOUSEHOLD
INCOME ($000) 1970
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32


SACRAMENTO
AUTO
OTHER
TRANSIT
TRIPS/HOUSEHOLD
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12.5
15
20
25
28
HOUSEHOLD INCOME ($000)


EINDHOVEN
AUTO
OTHER
BICYCLE
TRANSIT
TRIPS/HOUSEHOLD
INCOME ($000)
1970
0
1
2
3
4
5
6
7
8
0
2
4
6
6.9+


LINCOLN 1970
AUTO
OTHER
TRANSIT
BICYCLE
TRIPS/HOUSEHOLD
INCOME (1000 OF 1970 $)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
0
2
4
6
8
10
12
14
16
18
20
22

HAMBURG, WEST GERMANY, 1972



OTHER CONSIDERATIONS

External Adjustments

During the course of this project several areas were evident in which factors outside the scope of the developed models would affect the results of model application. The most important among these is the effect of varying economic conditions in the different countries on the income variable in the models. Another consideration includes the determination of proper categories for the independent variables. These aspects are discussed in the following sections.

Income -- Consistency between nations in the income scale for each of the relationships was achieved by first converting the respective monetary unit from the base year (in which the home interview data were collected) to a common year (1970). This was done using annual averages of consumer price indexes for all consumer items as shown in the following table:

Table 3

ANNUAL AVERAGES CONSUMER PRICE INDEX 22/
All Items
1963 = 100

Country	1961	'62	'64	'65	'66	'67	'68	'69	'70
Federal Republic of Germany*	97	100	102	106	110	111	113	116	121
Netherlands	94	96	106	111	117	121	126	135	141
United Kingdom	94	98	103	108	112	115	121	127	135
United States	98	99	101	103	106	109	114	120	127

*1962 = 100

22/ "Statistical Yearbook 1971," United Nations, New York 1972 (Table 176).

The conversion was then made to U.S. dollars at the conversion rate as of Dec. 31, 1970 and all curves were plotted on the same scale. The conversion rates used are shown below and the respective income ranges and points for plotting are shown in Table 4.

Federal Republic of Germany	1 D. Mark = $0.27
Netherlands	1 Gulden = $0.28
Great Britain	1 Pound = $2.40

No additional compensation was considered at the time of the analysis other than this simple conversion.*

It is evident, however, that other economic factors would operate in the relationships. This would be true intuitively and is borne out when one examines the basic curves. Generally shifts right or left along the horizontal (income) scale will place the curves in closer proximity of each other.

---

*NOTE: Should time permit, additional analysis may be conducted on the differences in the income affects prior to preparation of the final report and results will be reported on in this section.

Table 4
INCOME RANGES, CONVERSIONS
AND VALUES USED FOR PLOTTING

Lincoln, England (1970£ ; 1£ = $2.40)

Pounds	Mid Pt.	$	Value Assumed For Plotting
500	400	< 1,200	960
500 - 999	750	1,200 - 2,398	1,800
1,000 - 1,499	1,250	2,400 - 3,598	3,000
1,500 - 1,999	1,750	3,600 - 4,798	4,200
2,000 - 2,499	2,250	4,800 - 5,998	5,400
2,500 - 2,999	2,750	6,000 - 7,198	6,600
3,000 - 3,999	3,500	7,200 - 9,598	8,400
4,000 - 5,999	5,000	9,600 -14,398	12,000
6,000 & +	≈ 8,000	14,400 & +	19,200

Hamburg (1971 Study; 1970 1DM = $0.27)

		1970 DM	
< 3,600	≈ 3,000	2,835	777
3,600 - 5,988	4,800	4,535	1,242
6,000 - 9,588	7,800	7,370	2,019
9,600 -14,388	12,000	11,338	3,106
14,400 -21,588	18,000	17,008	4,660
21,600 -29,988	25,800	24,378	6,679
30,000 & +	≈33,600	31,748	8,698

Eindhoven (Vodar) (1970 Guilders; 1ƒ = $0.28)

	1970 $	$ Value Assumed For Plotting
< 5,000	< 1,389	≈ 1,000
5,001 - 10,000	1,390 - 2,778	2,090
10,001 - 15,000	2,779 - 4,167	3,480
15,001 - 20,000	4,168 - 5,556	4,868
20,001 - 25,000	5,557 - 6,944	6,257
Over 25,000	Over 6,945	≈ 10,000

Arnhem (1970 Guilders; 1 ƒ = $0.28)

	1970 ƒ	1970$
< 5,000	< 4,299	< 1,194
5,000 - 10,000	- 8,597	1,195 - 2,388
10,000 15,000	- 12,096	2,389 - 3,582
15,000 - 20,000	- 17,195	3,583 - 4,776
20,000 - 25,000	- 21,494	4,777 - 5,970
25,000 - 30,000	- 25,793	5,971 - 7,165
30,000 - 40,000	- 34,390	7,166 - 9,553
40,000 - 50,000	- 42,988	9,554 - 11,941
> 50,000	> 42,989	> 11,942

Tilburg (1972 Study; 1970 Guilders; 1f = $0.28)

	1970 $	f Mid Point	$ Value Assumed for Plotting
< 6,000	< 1,667	≈ 4,000	≈1,120
6,001 - 12,000	1,668 - 3,333	9,000	2,550
12,001 - 18,000	3,334 - 5,000	15,000	4,200
18,001 - 24,000	5,001 - 6,667	21,000	5,880
24,001 - 30,000	6,668 - 8,333	27,000	7,560
30,001 - 36,000	8,333 - 10,000	33,000	9,240
36,000 +	10,000 +	≈ 47,000	≈13,160

Factors that may bear on the economic differences might include differences in disposable income or real earnings, relative cost of new and used cars, and relative cost of operating a car or a combination of any of these. Since the biggest differences in the car ownership curves occur in the lower income ranges, the effects of relative household economic levels are greater here with respect to decisions about owning and operating a car. This follows from the obvious condition that auto ownership is limited primarily to those families that can afford the initial purchase and continuous operating expense of an automobile.

In a somewhat broader context Schoon discusses consumer categories and their available resources with regard to the purchase of desired transportation (or mobility).[23/] He indicates that the ability of one category of consumers of mobility, relative to other categories, to purchase mobility is dependent to a great degree on how disposable income is distributed between consumer categories and the amount of transportation (i.e., public or private) that is available for purchase within the consumer categories' purchasing power.

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23 / Schoon, J.G., "Consumer Equity Considerations and Trends in Purchasing Mobility," Proceedings of the International Conference on Transportation Research, First Conference, Bruges, Belgium, June 1973; Transportation Research Forum and College d'Europe.

If measures of the relative expenditure by a family (or group of families within a given income category) for transportation can be established for each country then a general method of normalizing the auto ownership and trip generation curves could be postulated. For example, consumer expenditure for cars and motorcycles in Great Britain was four percent of the total in 1971 and running costs of motor vehicles added another six percent.[24] In the U.S. in 1969 personal consumption expenditures for user generated transportation (new cars, tires, repair, gas, oil, etc.) was 12 percent of total consumption.[25] However, the percentage of a family's disposable income used to purchase transportation varies with the family income level. In terms of a representative average urban family of four in the U.S. the amount the family can spend for transportation varies with the total family budget as shown below for autumn 1971 conditions:

24/ From "National Income and Expenditure, 1972" as reported in "Britain, 1973, An Official Handbook," Her Majesty's Stationery Office, London, 1973.

25/ "National Income and Product Accounts, 1964-1969," U.S. Department of Commerce, Bureau of Economic Analysis, Washington, D.C., July 1973.

	Lower Budget	Intermediate Budget	Higher Budget
Total Budget	7,214	10,971	15,905
Total Consumption	5,841	8,626	11,935
Transportation	536	964	1,250
% of Total Budget	7.4	8.8	7.9
Other Items	357	560	937
Taxes	1,016	1,785	3,033

Source: Ruiz, Elizabeth, "Urban Family Budgets Updated to Autumn 1971," Monthly Labor Review, Vol. 95, No. 6, June 1972.

Tanner discusses the effects of total expenditure per person on the average number of cars per person in Great Britain based on the 1972 Family Expenditure Survey.[26] Postulated increases in total expenditure of 25 and 100 percent result in increases in cars per person of about 32 and 85 percent respectively over the 1972 level of 0.212 cars per person.

Due to many of the conditions mentioned earlier in the section on the "Urban Complex," and the examples just discussed, the effects of family expenditure budgets or disposable income levels are important determinents of auto ownership and trip generation. These effects should explain, to some degree, the differences between auto ownership and trip generation distributions between countries.

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[26] Tanner, J.C., "Forecasts of Vehicles and Traffic in Great Britain: 1974 Revision," TRRL Laboratory Report 650, Transport and Road Research Laboratory, England, 1974.

Variable Stratification--The categories of the two independent variables used in the cross-classification analysis were predefined by the coded data already in the data sets received from the delegate of the participating nations. For example, car ownership extended to two or more cars in some cases, and to three or more in others. The ranges of income that formed each category were in form of codes to facilitate data processing and any deviation was not possible.

Often, however it is desirable, and necessary, for the analyst to evaluate the cross-classification results with regard to the way the independent variables were structured for the input. The strength of the cross-classification technique is based on the need to maximize the logical structuring of the variables and if handled carefully the amount of statistical evaluation required can be minimized. Those statistical checks that can be used are discussed in the next section.

In developing the cross-classification matrix some "rules of thumb" can be considered. First the number of observations in any cell in the matrix should be large enough so that the mean trip rate for any category is representative of all the households within that category. From a statistical point of view this number is typically around 25 to 30 observations, although from the practical side this number is often less. Where there are too few observations solutions can range from combining the "thin" category with another and rerunning the cross-

classification procedure to "ignoring" the particular cell data point when the results are plotted. In the latter case the proper point on the smoothed curve would represent the trip rate from the cell with too few observations. If the rationale and logic in trip generation is followed this value would be more appropriate for forecasting purposes.

One of the products of the XCLASS program is the standard deviation of the trip rate by cell. Where the cell standard deviation is large with respect to the mean trip rate for that cell, the category ranges can be reevaluated to determine if new categories should be used or if certain matrix cells should be subdivided. A plot of the frequency distribution of observed rates for the cell in question can be helpful in identifying how well the cell mean trip rate represents the tripmaking of all households in that cell.

The above mentioned aspects are important points that should be considered in evaluating and improving the effectiveness of the trip generation method.

Other Factors

As discussed earlier in this paper, income and auto ownership have been found to be two of the most important indicators of urban travel. This is true not only for explaining the variance in trip making, but for improved accuracy in forecasting.* Other household variables, of which structure type stage in the family cycle and number of employees are typical, are not as good predictors of travel and are more difficult to forecast and use in the trip generation analysis. Family size was introduced in the project analysis to indicate the additional variation that could be explained by its use and as a surrogate for some measure of density or transit availability. A small measure of success was achieved in doing this. The overall effect of density on auto ownership levels was shown in Figures 9a and 9b which differentiated between relatively dense central city and the less dense suburbs.

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* In a recent analysis of 1960 survey data from Philadelphia, Pennsylvania, conducted in conjunction with the study update, income and car ownership together explained 24% of the total variation in household trip generation. This was only a little less than car ownership and family size (27%) and income and family size (26.4%).[27] The use of family size, however, offers the analyst some degree of difficulty in forecasting. For example, family size on the average (at least in the U.S.) has tended to drop recently. If this drop were assumed to continue in the future, the average household would "shift back" into a lower trip rate. Household tripmaking, however, has been increasing on the average and if this were to continue, the use of family size would tend to under estimate total trip production.

27/ "Interim Report on Trip Generation," A working prepared for Delaware Valley Regional Planning Commission by Creighton, Hamburg, Inc., July 1974.

It was hypothesized before the Phase II analysis, however, that differences in cities as measured by differences in density and/or transit usage would account for much of the difference found in trip generation. These effects in general were seen earlier in the section on the "Urban Complex," and it was intended that system and/or density variables would be added to the analysis.*

System Supply and Level of Service--There has been some research conducted recently in an attempt to incorporate a measure of the transportation system in trip generation analysis.** While most of this work has met with mixed degrees of success, from a practical point of view system sensitivity has not often been incorporated into this element of an operational transportation planning process.

In one research effort, for example, it was found that the addition of an accessibility variable in person trip production equations using data from Indianapolis, Indiana did not improve the relationships appreciably.[28] (A degree of success was, however, achieved on the attraction side, indicating perhaps the effects of market area influence

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* Note: While limitations have precluded the addition of these variables for this draft of the report, analysis will continue in anticipation of meeting in late summer deadline for the final report.

** An extensive discussion of this within the broader context of the highway supply/travel demand relationship may be found in: Zimmerman, S., West, M., and Kozlowski, T., "Urban Highways as Traffic Generators," Federal Highway Administration, Urban Planning Division, Washington, D.C., August 1974.

28/ Nakkash, N.Z. and Grecco, W.L., "Activity-Accessibility Models of Trip Generation," Highway Research Record No. 392, Highway Research Board, Washington, D.C. 1972.

on the attractor). Other efforts have been made to include system sensitivity in trip generation analysis, but have generally found that this type of variable was not significant when compared with socio-economic variables of the tripmaker or his household.[29] [30]

Zahavi has suggested that an individual considers his total daily travel in terms of a "budget" and that, as he makes trips his budget would be "drawn down" until it was completely expended for the given time period.[31] It is suggested that an individual would trade off his budget or "cost" (often referred to as disutility) of travel with the benefits achieved for having made the trip. The cost of the trip or disutility to the tripmaker would be influenced to a great degree by the level of service of the transportation system over which the potential trip is to be made. In another effort the Federal Highway Administration sponsored a study to develop effective

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29/ Koppleman, F.S., "Preliminary Study for Development of a Macro Urban Travel Demand Model," (In draft), Massachusetts Institute of Technology, 1972.

30/ Voorhees, A.M., "A System Sensitive Approach For Forecasting Urbanized Area Travel Demands," prepared for U.S. Department of Transportation, Washington, D.C. 1971.

31/ Zahavi, Yacov, "Traveltime Budgets and Mobility in Urban Areas," Federal Highway Administration, Washington, D.C. 1974.

ways of obtaining information on traveler responses to changes in transportation system supply.[32] An outgrowth of this work is a case study of a specific project to examine the behavioral adaptation to the change in the transport system as result of the project.[33] Gur calibrated and tested a model using Chicago data which incorporated the effect of access on travel demand.[34] He found that generation of trips over three miles long was only slightly sensitive to accessibility measures.

System variables have been extended to auto ownership estimation as well. For example, Lerman and Ben-Akiva studied the probability of a household choosing various auto ownership and mode to work combinations through a series of disaggregate behavioral models.[35] Dunphy shows that there is a statistically significant relation between transit accessibility* and automobile ownership, even when other significant household variables of family size and income are held constant.[36]

Fewer examples of system variables in trip generation and auto ownership analysis can be found in on-line operational transportation studies, however. One recent application in Washington, D.C. utilized a

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* The percentage of jobs reached from an area in 45 minutes by transit.

32/ "Design of Procedures to Evaluate Traveler Responses to Changes in Transportation System Supply," Conference Summary and White Papers, Federal Highway Administration, Washington, D.C., September 1974.

33/

34/ Gur, Yehuda, "An Accessibility Sensitive Trip Generation Model," Chicago Area Transportation Study, Chicago, Illinois, October 1971.

35/ Lerman, S.R. and Ben-Akiva, M., "A Disaggregate Behavioral Model of Auto Ownership," presented at the Fifty-Fourth Annual Meeting, Transportation Research Board, Washington, D.C., 1975.

36/ Dunphy, R.T., "Transit Accessibility As A Determinant of Automobile Ownership," Highway Research Record No. 472, Highway Research Board, Washington, D.C., 1973.

measure of transit accessibility along with income and family size in the "shopping" and "other" trip production relationships for the regional forecasting models.[37] In another application in the U.S. a measure of accessibility to employment by transit (a function of the traveltime from the home zone to all work zones by transit compared to this value for other home zones) was added as a third independent variable in the auto ownership cross-classification analysis.[38]

While the research effort involved to explicitly study system effects was beyond the scope of this subproject, it is suggested that this would be one of the most fruitful areas of further analysis.

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[38] "Traffic Models and Modal Split Development, Technical Memorandum Number 2," Jacksonville Urban Area Mass Transportation Study, Jacksonville Area Planning Board, Jacksonville, Florida, June 1973.

Statistical Evaluation--One of the most important attributes of the cross-classification approach is the way in which the user is required to rely on a basic rationale and logic in trip generation relationships. While there is relatively little opportunity to test the statistical significance of the relationships (as normally available in regression analysis), there is a statistical procedure which has been identified to aid in this objective.

For example, Chatterjee and Khasmabis indicate that statistical significance tests can be performed with factorial analysis and sometimes with least squares regression.39/ The objective of factorial analysis is to determine the main effects and interactions of variables in a cross-classification analysis and to test their significance. The main effect of a factor is determined from the average value of the dependent variable for each level of the factor. This is accomplished by holding the effects of other variables constant across the levels of the main effect being examined. The differences, if any, between the values for consecutive levels indicate the effect of the factor on the dependent variable. In addition, the authors suggest that analysis of variance will provide a test to compare the variation of the dependent variable that can be attributed to the individual factors with that variation which can be attributed to chance or random errors.

39/ Chatterjee, A., and Khasmabis, S., "Category Models--A Case for Factorial Analysis," Traffic Engineering Magazine, Institute of Traffic Engineers, October 1973, pp. 29-33.

The significance tests of individual factors and their interactions can be performed by means of "F" tests. Computer programs BMDO2V, "Analysis of Variance for Factorial Design," and BMDO5V, "General Linear Hypothesis," 40/ can be used to perform this analysis.*

40/ "BMD Biomedical Computer Programs," W.J. Dixon, Editor, University of California Press, Berkeley, California, 1974.

* The Federal Highway Administration is currently researching further the application of a General Linear Analysis of Variance. Application will be facilitated by the development of computer software.

APPLICATION

The procedure outlined in this report is a workable, tested trip generation analysis method which will help reduce expenditures of planning resources. The forecasting approach is based on the use of household data in a cross-classification analysis for the residential (or home-based production) trip generation, and the result becomes a control of total region-wide tripmaking.* The amount of home end travel generated (total home-based trip productions) is a function of the number of households and the household characteristics of income and auto ownership. This residential trip generation is based on a two step process.

The first step utilizes an auto ownership model which incorporate the relationship between the percent of households with a given auto ownership and household income. The second step relates total person trips per household to auto ownership and income. In both steps an additional variable (density is suggested) can be included to further explain differences in tripmaking.

There are a number of attributes of a good forecasting procedure and which are also indicative of the trip generation models developed for this subproject:

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* Trip attraction estimation by several different methods is described elsewhere. See: "A Simplified Approach to Trip Generation Analysis," (in draft) prepared by Comsis Corporation for Federal Highway Administration to be published Summer 1975.

1. Understandable -- The procedure must be understandable to those who use the output as a basis for making decisions on future courses of action as well as to the analyst developing the forecasts. Government officials and decisionmakers as well as the public can easily grasp the idea of trips as related to household characteristics and see how household tripmaking is likely to change as household characteristics change.

2. Efficient -- The household level analysis can be developed using less data than other conventional models. Its application is not governed by the amount of data required to run it.

3. Easily Monitored and Updated -- The form of the relationship allows monitoring the trip rates through small sample surveys or supplemental data sources and site analysis to check particular trip rates.

4. Policy Sensitive -- The procedure can be made policy sensitive by introducing factors representing relevant issues into the cross-classification procedure. For example, one can assess the impact of differing population density levels and auto ownership saturation levels can be evaluated.

5. Non-geographic Specific -- Since the approach is based on household level data for residential trip generation, the rates are applicable to any area level of study. For example, the rates may be applied to districts, zones, or subzones for regional study, corridor study, or new development evaluations, etc.

6. Transferable -- This attribute is at the center of this sub-project. Because relationships have been developed at a more basic "behavior" unit with "standard" variables, synthesis or "borrowing" of rates from one area and applying them to another can be facilitated.

7. Use Census and National Survey Data -- Since the procedure uses "standard" indicators of travel (income and auto ownership) national censuses and surveys can often supply the input to apply the basic relationships.

8. Valid in Forecasting -- The procedure is valid for forecasting as well as in base year accuracy.

The above attributes are among the most important considerations for forecast model application. Each of these has been considered and incorporated in the trip generation procedures outlined in this project.

PROCEDURE FOR APPLICATION

The procedure for applying the basic relationships is illustrated in Figure 16. The basic input would be a forecast of total households for the area of interest (zone, district, corridor, study-area, etc.) and the appropriate income value (or values) for the area in question (see next section for a discussion of income estimation). The result of applying Curve 1 and multiplying by the number of households is the number of households by auto ownership class. For models with a third independent

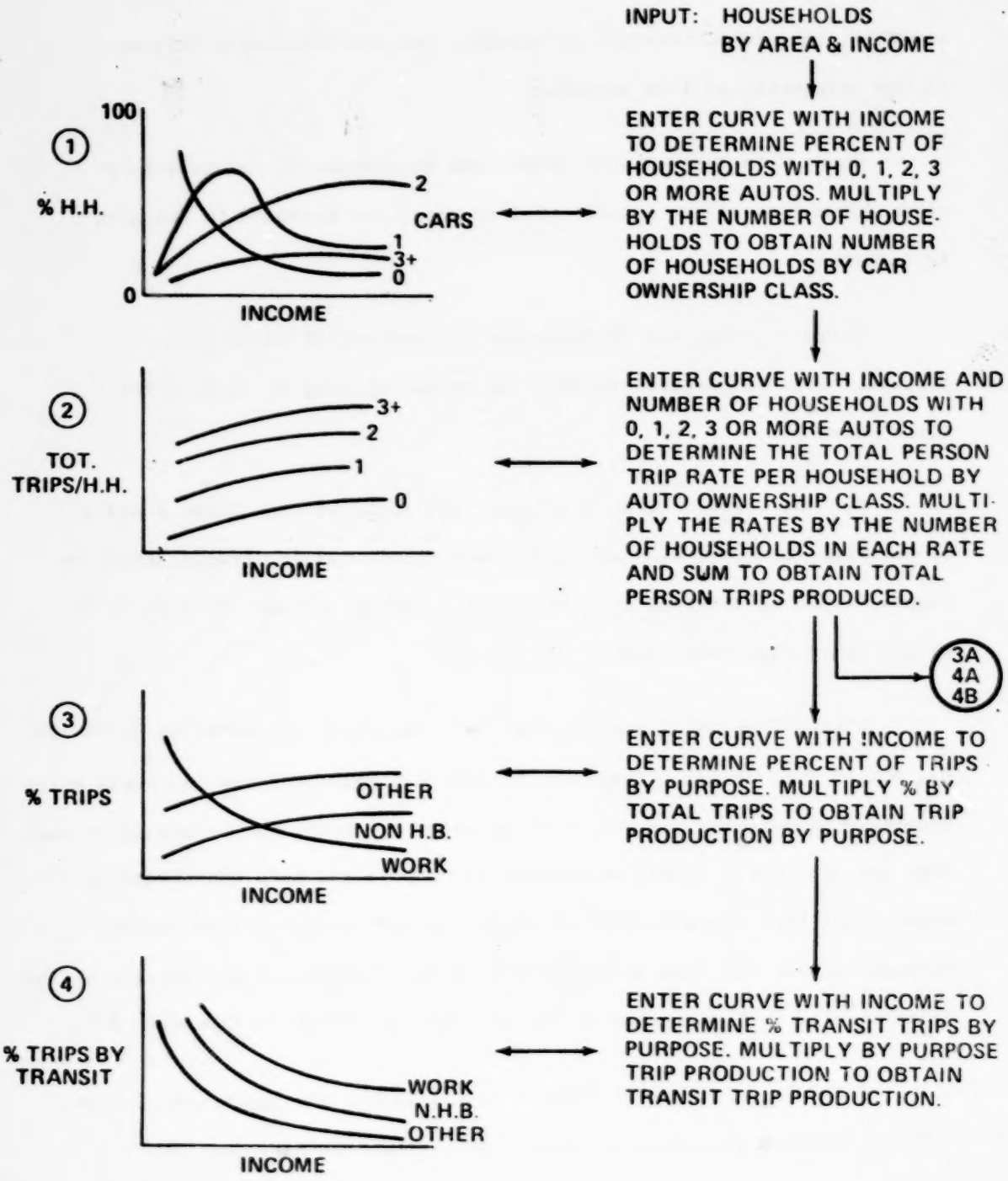

INPUT: HOUSEHOLDS BY AREA & INCOME
ENTER CURVE WITH INCOME TO DETERMINE PERCENT OF HOUSEHOLDS WITH 0, 1, 2, 3 OR MORE AUTOS. MULTIPLY BY THE NUMBER OF HOUSEHOLDS TO OBTAIN NUMBER OF HOUSEHOLDS BY CAR OWNERSHIP CLASS.
ENTER CURVE WITH INCOME AND NUMBER OF HOUSEHOLDS WITH 0, 1, 2, 3 OR MORE AUTOS TO DETERMINE THE TOTAL PERSON TRIP RATE PER HOUSEHOLD BY AUTO OWNERSHIP CLASS. MULTIPLY THE RATES BY THE NUMBER OF HOUSEHOLDS IN EACH RATE AND SUM TO OBTAIN TOTAL PERSON TRIPS PRODUCED.
3A
4A
4B
ENTER CURVE WITH INCOME TO DETERMINE PERCENT OF TRIPS BY PURPOSE. MULTIPLY % BY TOTAL TRIPS TO OBTAIN TRIP PRODUCTION BY PURPOSE.
ENTER CURVE WITH INCOME TO DETERMINE % TRANSIT TRIPS BY PURPOSE. MULTIPLY BY PURPOSE TRIP PRODUCTION TO OBTAIN TRANSIT TRIP PRODUCTION.
1
100
% H.H.
0
2
CARS
1
3+
0
INCOME
2
TOT. TRIPS/H.H.
3+
2
1
0
INCOME
3
% TRIPS
OTHER
NON H.B.
WORK
INCOME
4
% TRIPS BY TRANSIT
WORK
N.H.B.
OTHER
INCOME

FIGURE 16

EXAMPLE OF TRIP PRODUCTION ESTIMATION

variable, the procedure would be repeated for the households falling in the categories of that variable.

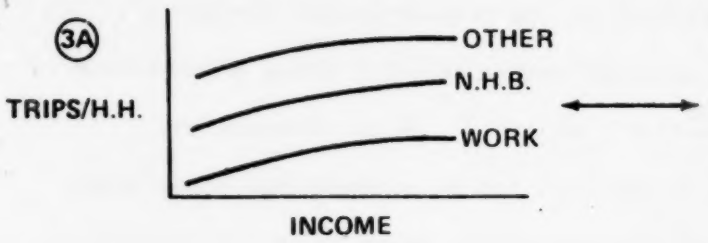
Curve 2 is applied with income and households by car ownership class (from Curve 1) to obtain total person trips produced in the area in question.

Curve 3 is applied to determine the percent of total trips by purpose. Trip by purpose are obtained by mutliplying by total trips (from Curve 2).

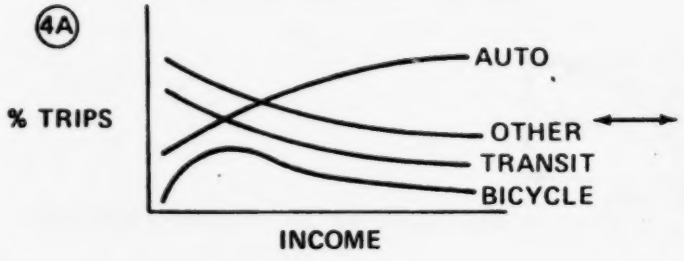
Percent transit trips by purpose are obtained from Curve 4 again, by entering the model with an appropriate income value. Transit trips by purpose would be obtained by multiplying trips by purpose (from Curve 3) by the percentage value found from Curve 4.

Alternative relationships that were developed are shown in Curves 3a, 4a, and 4b (Figure 17). These are alternative relationships to obtain trips per household by purpose, percent trips by mode, and trips per household by mode. They are useful for direct estimation of purpose and mode (particularly for modes other than transit, such as bicycle), but the interrelationship between purpose and mode as in Curve 4 is not available. Application of the relationships is facilitated by the programs described in Appendix B.

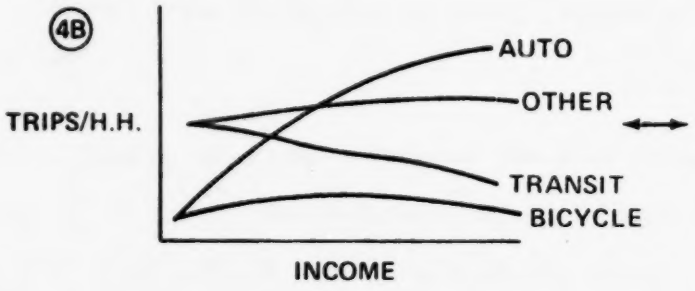
A simple hypothetical example to illustrate the application of the trip production estimation procedure is included in Appendix C.



ENTER CURVE WITH INCOME TO DETERMINE TRIPS PER HOUSEHOLD BY PURPOSE. MULTIPLY EACH RATE BY TOTAL HOUSEHOLDS TO OBTAIN TOTAL TRIP PRODUCTION BY PURPOSE. (SUM AND ADJUST WITHIN TOTAL TRIP PRODUCTION FROM CURVE (2)).



ENTER CURVE WITH INCOME TO DETERMINE % TRIPS BY MODE. MULTIPLY % TRIPS BY TOTAL TRIP PRODUCTIONS FROM (2) TO OBTAIN TRIP PRODUCTIONS BY MODE.



ENTER CURVE WITH INCOME TO DETERMINE TRIP PRODUCTIONS BY MODE DIRECTLY. (SUM AND ADJUST WITHIN TOTAL TRIP PRODUCTION FROM (2)).

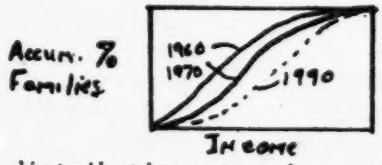
FIGURE 17

EXAMPLE OF TRIP PRODUCTION ESTIMATION
ALTERNATIVE RELATIONSHIPS

Income Forecasting

A key variable in the procedure is income. In most instances the estimates of this variable are provided to the transportation planner as a result of economic and land use forecasting normally being accomplished as a part of region-wide comprehensive planning.* As an alternative, there are methods of forecasting income that can be accomplished along lines that are similar to the simplified trip generation approach in this subproject.

The procedure is based upon an examination of regional income distributions for several past time periods--in constant monetary units, as shown:



Historical income distributions are then extrapolated to the future condition based upon knowledge of the changes in proportions of families in each of several income ranges. For example, historically the percent of families in lower income ranges has been decreasing while the percent in upper ranges has been increasing.

Two characteristics discussed by a New York study on income growth provide a basis for forecasting regional income distributions. 41/ The study indicated that for the lowest income class (under $3,000) the rate of income growth is about 1.5 times that for the $10,000-$15,000 income class and that the percent of income in quintiles of the population remains

* For example, given a regional distribution of income, current land use models (EMPIRIC and PLUM) will provide allocations of household income to small analysis units.

41/ Donnelly, Elene, "Differential Income Growth in the United States, 1960-1969," New York Department of Transportation, May 1972.

relatively stable overtime.* Using these two characteristics the current income distribution is "advanced" to the future by applying different income growth rates for each quintile of the families that make up the distribution to reflect the differential growth. An average income growth rate is assumed as the basis for the quintile growth rates. The hypothetical distributions resulting from the above procedure are shown in Figure 18.

If the resultant forecast curve does not appear to fit past trends or does not fit known local conditions in the region, alternative growth rates may be used to re-calculate the future distribution. The procedure is iterative in nature, requiring the application of differential growth factors to income ranges and the subsequent plotting of the resulting distribution to determine if the distribution appears to "fit" the historical and other known changes in income.

Once an acceptable regional income distribution is obtained, individual small area (zone, district, subzone, etc.) income estimates are required. These can be forecast by knowing the average household income for the zone (or groups of households) and using the appropriate growth factor used in the regional distribution forecast. For example, assume the regional growth factor for incomes between $10,000 and $14,000 was 1.81.** Then all zonal average household incomes between $10,000 and

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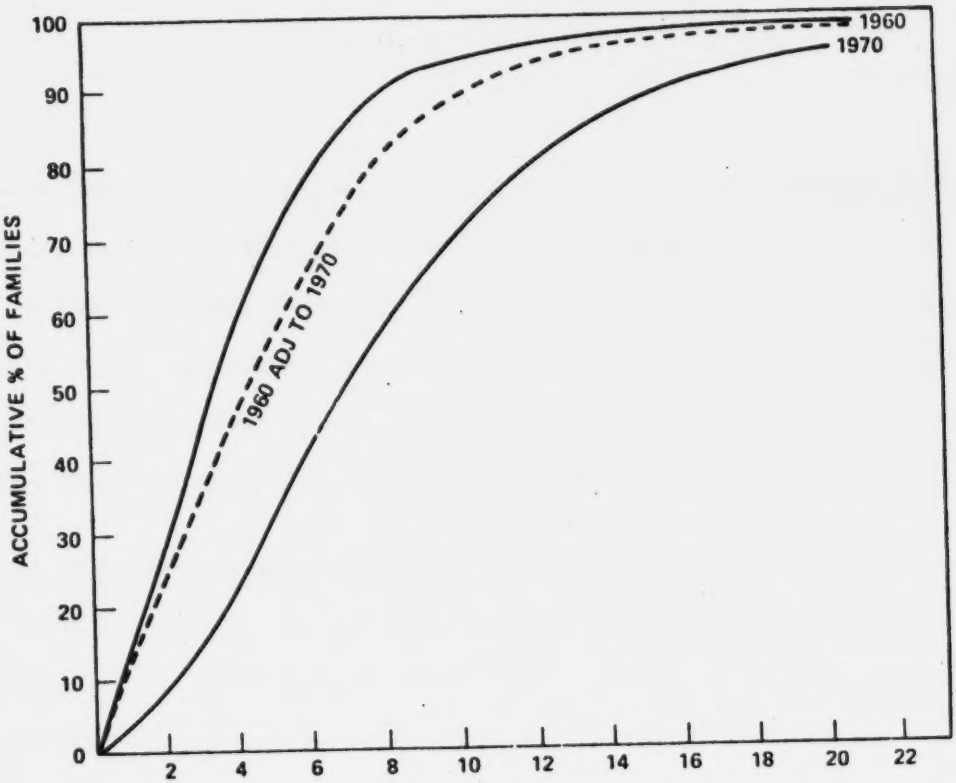
* This latter characteristic is often studied in terms of the Lorenz curve in which the distribution of income can be compared with the distribution of families.

** Based on a 3% annual compound growth rate over 20 years.



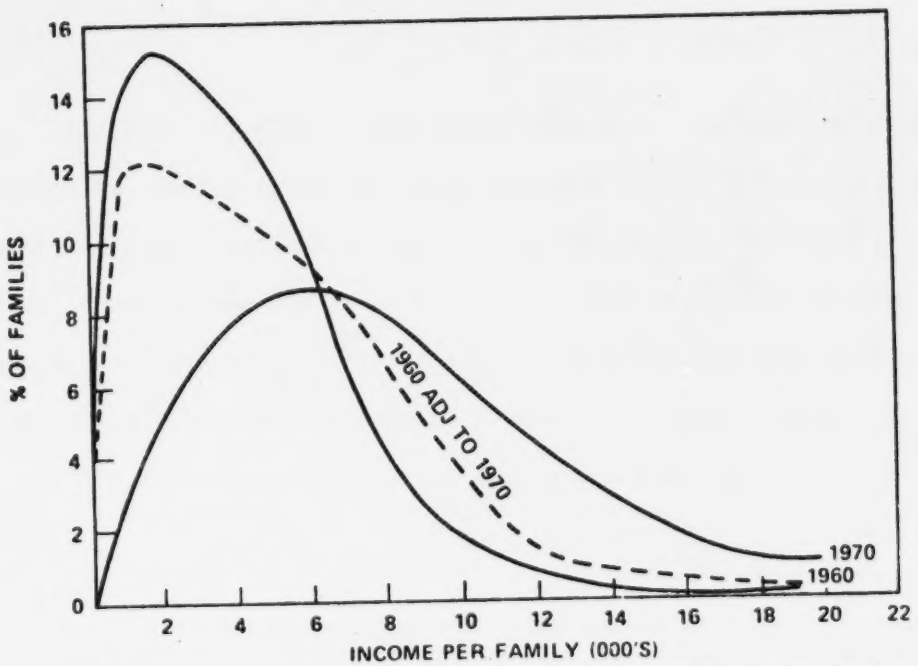
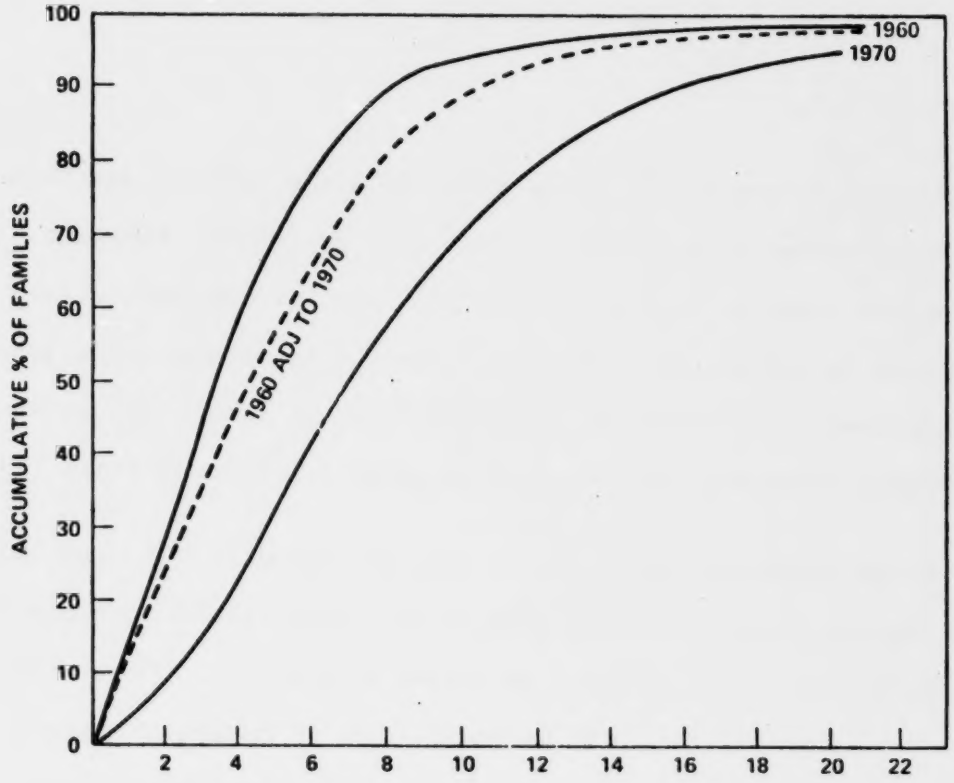


FIGURE 18. ADJUSTMENT OF 1960 CURRENT DOLLARS TO 1970 CONSTANT DOLLARS



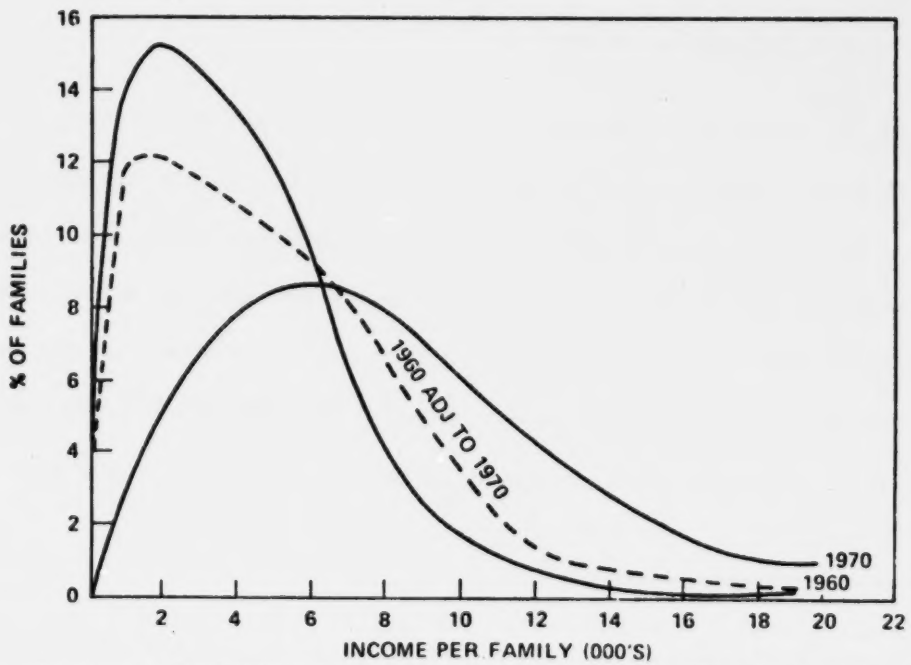


FIGURE 18. ADJUSTMENT OF 1960 CURRENT DOLLARS TO 1970 CONSTANT DOLLARS

$14,000 would receive the same growth factor.

It is useful to know the likely distribution of households for some future time within a zone or group of households, given an average income value for the zone or group. An income distribution model, based on origin-destination study data can be developed similar to one based on the Charlotte, North Carolina transportation study.[42] The development of this model is shown in Figure 19a. The resultant set of distributions is shown in Figure 19b.

Household data are used to calculate a zonal average household income. All zones are then arrayed by average income from low to high and strata are cut, resulting in categories of incomes (e.g., low, medium, high). The individual household incomes in each zone within each strata are then used to develop the percentage value of households at each of several income values (e.g., every $1,000). These points are plotted and smooth curves are fitted through them.

The distribution would be applied by entering the set of curves at an average zone value of income and reading off the percent of households in each income category (e.g. low, medium or high). The remaining curves

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42/ "Charlotte-Mecklenburg Urban Area Transportation Study, Report on Mathematical Modeling," North Carolina State Highway Commission, September 1972.

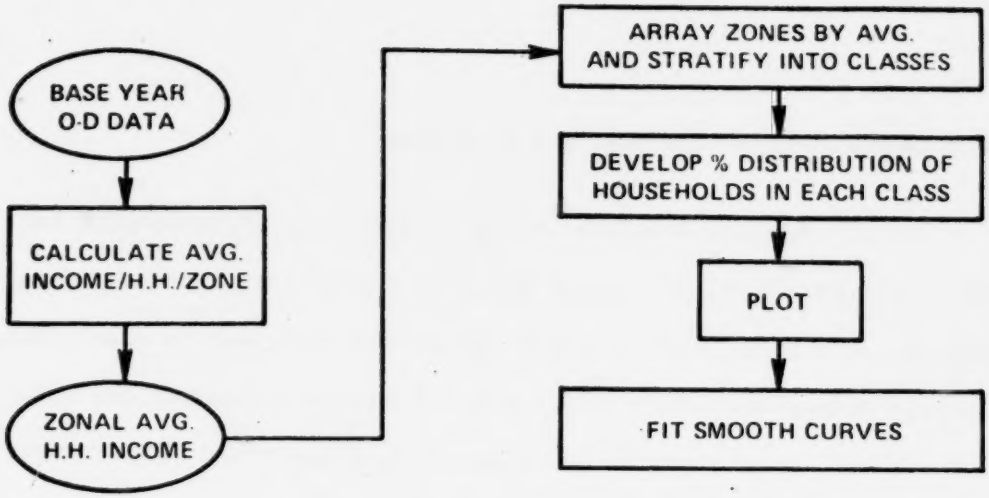
BASE YEAR O-D DATA
CALCULATE AVG. INCOME/H.H./ZONE
ZONAL AVG. H.H. INCOME
ARRAY ZONES BY AVG. AND STRATIFY INTO CLASSES
DEVELOP % DISTRIBUTION OF HOUSEHOLDS IN EACH CLASS
PLOT
FIT SMOOTH CURVES

FIGURE 19A

DEVELOPING INCOME DISTRIBUTIONS

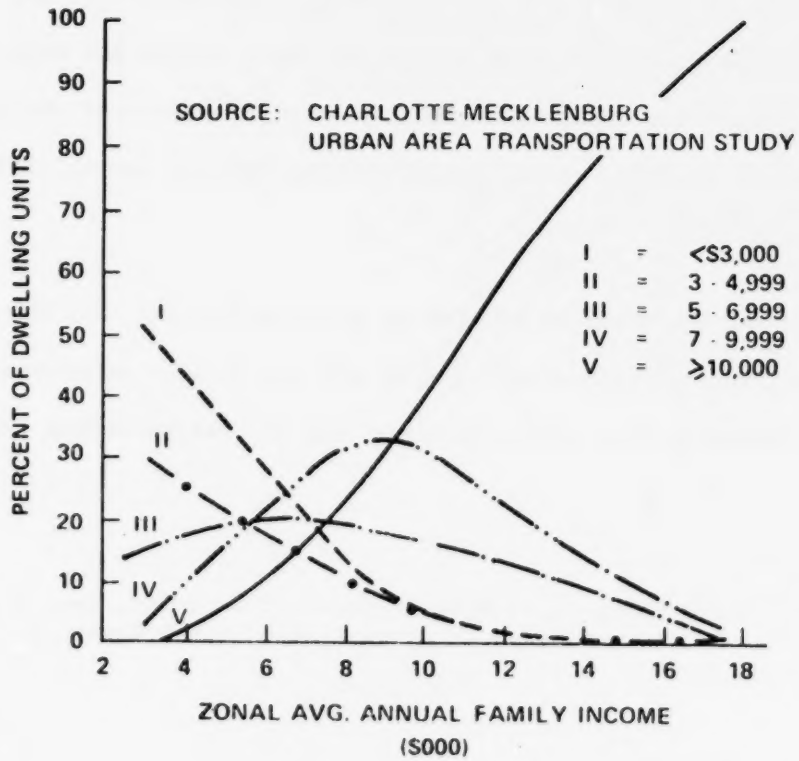
SOURCE: CHARLOTTE MECKLENBURG URBAN AREA TRANSPORTATION STUDY
I = <$3,000
II = 3 - 4,999
III = 5 - 6,999
IV = 7 - 9,999
V = ≥10,000
PERCENT OF DWELLING UNITS
ZONAL AVG. ANNUAL FAMILY INCOME ($000)

FIGURE 19B

(1 through 4 as discussed in the previous section) would be applied once for each income category and summed at the end.

A similar method of developing income distributions has utilized 1970 census data in the U.S. Census tract averages of household income were used in a manner similar to that described above to develop the distribution shown in Figure 20.

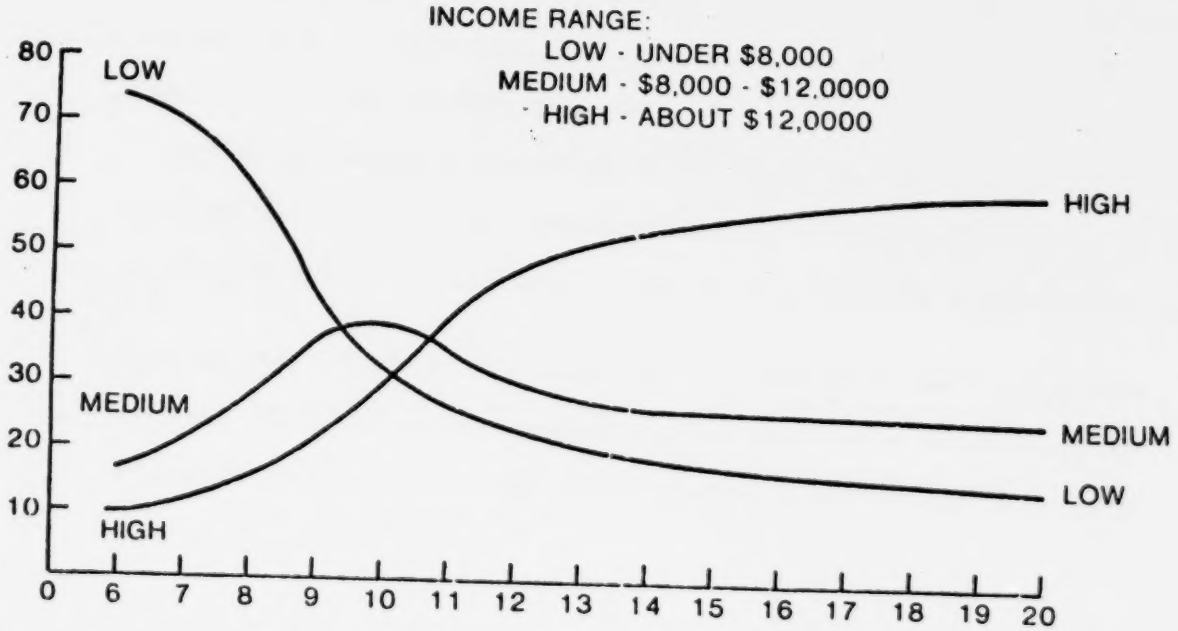

FIGURE 20 INCOME DISTRIBUTION BY TRACT IN LOW, MEDIUM & HIGH INCOME RANGES

TRAVEL ESTIMATION

The procedure outlined in this project was oriented to providing a quick estimate of likely number of trips produced under varying socio-economic conditions. The number of trips produced in an urban area, however, does not provide a complete picture of travel demand for the area. This was discussed in the section on "Objectives of the Subproject" which indicated the limits of this present work reported on here and possible extensions to the project. It is important, however, that the broader aspects of travel, not just trip ends, but a measure of the extent of the trips produced (motorization), be mentioned.

A useful measure of the extent of travel is the vehicle mile or vehicle kilometer and the relationship of travel (vehicle miles of travel) to economic levels on an macro scale was discussed earlier in the section on the urban complex. Other socio-economic factors could be mentioned as having an effect on travel including the age distribution of the population, the number of licensed drivers, fuel availability and price, and settlement patterns and the spatial distribution of the population.

Within the frame of reference of this project, income and auto ownership have been shown to be important determinants of travel.[43/44/] The relationship, on a national scale between income and cars was presented earlier

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43/ Nationwide Personal Transportation Study, Federal Highway Administration, Washington, D.C.

44/ Tanner, J.C., "Forecasts of Vehicles and Traffic in Great Britain: 1974 Revision," TRRL Laboratory Report 650, Transport and Road Research Laboratory, England, 1974.

in the "Results" and was oriented to trip generation estimation. Household travel (vehicle miles) also increases as the level of household income rises as seen below.[45]

Annual Household Income	Annual Vehicle Miles per Household
< $ 4,000	4,708
$ 4,000-$ 9,999	12,262
$ 10,000-$14,999	17,497
$ 15,000 and over	24,410

Household travel also varies with the number of autos available to the household.[45]

Cars/Household	Daily Vehicle Miles per Household
0	4.8
1	28.4
2	58.7
3 or more	82.1

Based on 1972-73 National Travel Survey information in Great Britain the effect of income is illustrated:

	Kilometers Per Car Per Week			
Per Person Per Year	1 Car	2 Cars	3 or More Cars	All Households
0-	230	245	255	235
500-	245	220		240
750-	270	265	255	270
1,000-	280	280	240	280
1,500-	315	260	190	290
2,000-	310	240		270
All	260	255	240	260

Source: Tanner, J.C., "Forecasts of Vehicles and Traffic in Great Britain: 1974 Revision," TRRL Laboratory Report 650, Transport and Road Research Laboratory, England, 1974.

45/ Nationwide Personal Transportation Study, op. cit.

Travel by a household is also influenced to a great degree by the location of the household within the urbanized area, apparently reflecting such things as auto ownership and density of activity. For example, the following figures resulted from a 1968 travel survey in Washington, D.C.[46]

Residence Location (Ring)	Average Daily Auto Miles Driven per Household*		
	Work	Non-work	Total
0	1.5	2.2	3.7
1	1.8	4.3	6.1
2	3.4	5.5	8.9
3	6.3	9.0	15.3
4	10.5	16.8	27.3
5	15.1	21.9	37.0
6	15.4	24.4	39.8
7	22.0	23.7	45.7

*Includes car-owning and non-car-owning households.

Travel forecasts have often been made, particularly on a national scale, based on population, income, or vehicle registrations, but not often incorporating the combined effects of varying auto and income levels at the same time. The same advantages of using the income-auto ownership relationships for trip generation purposes can be beneficial for travel generation as well. Forecasts of VMT have not often been made directly from estimates of future socio-economic levels in transportation studies. It is felt, however, that this is an important enough part of forecasting to warrant its mention in this report.

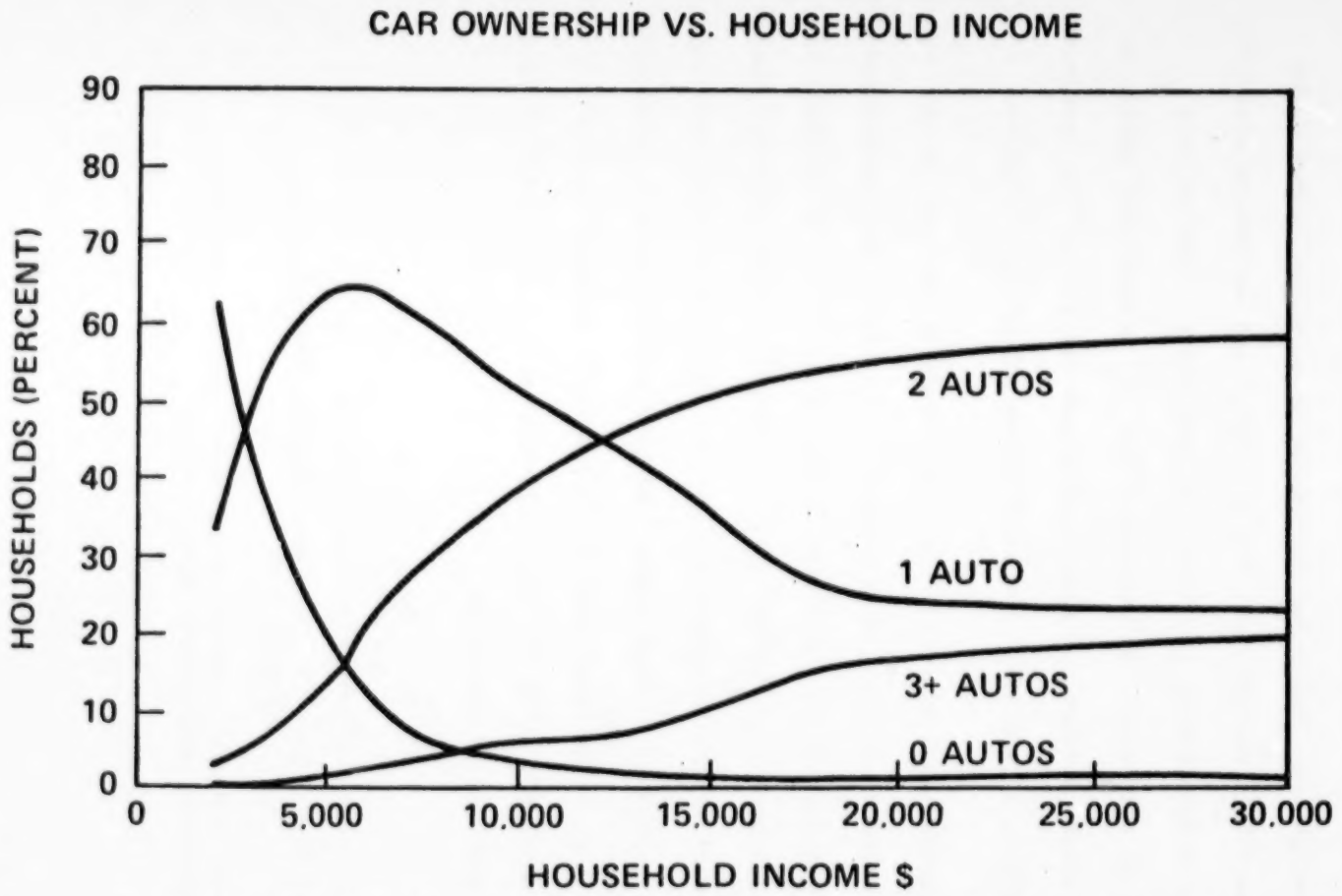
46/

VMT estimation could serve several valuable purposes. Vehicle miles of travel is made up of trips produced and their length. By assuming an overall average trip length for the region in question (either known or "borrowed" from another, and similar, area) and estimating area-wide VMT through a forecasting technique, an independent check on trip generation is available. By varying either the assumed trip length or trip production, a rough but easily developed estimate of the resultant regional travel is available for alternative policy consideration.

National censuses and travel surveys often provide the type of data required to estimate travel at a national scale. For example, the cross-classification procedure was applied in the United States to arrive at an estimate of total vehicle miles of travel for the nation in 1990.[47/] Latest national census projections of income distributions and the basic income-auto ownership relationships (Figure 21) and travel per household based on a nationwide transportation survey[48/] were used in this study. Results in terms of estimated compound annual growth in VMT over a 20-year period were within 4 percent of two other independent estimates.

47/ "Highway Travel Forecast," Federal Highway Administration Washington, D.C., November 1974.

48/ Nationwide Personal Transportation Study, Federal Highway Administration, Washington, D.C.



SOURCE: ESTIMATED FROM NATIONWIDE PERSONAL TRANSPORTATION STUDY, 1969-70, FHWA.

FIGURE 21

SUMMARY

COMMENTS ON THE SUBPROJECT RESULTS

This subproject explored the generality of travel demand characteristics as viewed from an international perspective. More specifically it tested the ability to develop a generalized trip generation procedure that could be utilized quickly and easily on a multi-country basis to provide information on tripmaking that would likely occur under varying assumptions of socio-economic activity. The project results demonstrate a usefulness to decisionmakers, by providing information on potential trip generation activity likely if trends in motorization continue. Experience in European urban areas were contrasted with U.S. conditions both from a national perspective and specifically for the cities analyzed in Phase II. Specific recommendations on application of the trip generation procedure were presented in the previous section of the report. While the cross-classification idea is not new, the specific approach used in this project reflected a definite rationale for trip generation analysis where such has often been lacking in the past in transportation planning from a practical point of view. The specific methodology discussed in this report and has been tested and applied under operational transportation planning conditions.

Taken on an individual city by city basis, the curves tend to reinforce in a simple and uncomplicated way the underlying concept of how auto ownership and socio-economic status operate on the frequency of tripmaking. Taken collectively the curves all show the same general pattern of the effects of these two indicators. The fact that the patterns are relatively stable for different countries is notable and the project was successful in identifying this aspect of the relationships.

Additional effects on the curves were discussed and several variables identified as having an influence on the application of the relationships. One of the most important, as might be expected, is the effect of varying economic conditions in the different countries as they affect mobility. Within this broad area, the ability of a consumer (or category of consumers) of transportation or mobility to purchase this commodity is due in large part to that consumer's disposable income.

The development of complex functional relationships in order to better "fit" the international data sets was not tried. Simple hand fitting of the curves, in a manner suggested for transportation study

application, on an individual city basis was done to explore the patterns of the different relationships. In effect this proved that the same methodology was applicable across cities in different nations.

More far-reaching and sophisticated (and complex) modeling of travel behavior is being researched and will probably be available in the future. However, the procedure suggested in this project is simple to use and understand and is available now for ready use under conventional travel model constraints with traditional transportation and transportation related data. The procedure thus provides a way of conveniently looking at travel trends and quantifying the effect of alternative trends for practical use.

While the subproject covered only one aspect of the total travel demand picture this does not mean that other aspects are not as important. It is also clear that there are several immediate and logical extensions that might be made to this specific subproject. Recommendations for further work are included in the following section.

RECOMMENDATIONS FOR FURTHER ANALYSIS

The findings of this work were significant enough to warrant consideration of an extension to this subproject. Additional work might be accomplished under an overall objective aimed at furthering the capacity of the technical travel demand forecasting process to deal with alternative policy considerations. Under this approach two broad areas are suggested by the work in this subproject and by other recent research:

(1) Extension of work along the lines of the traditional planning process, and

(2) Work toward new procedures or approaches.

Under the first alternative three areas of work might be considered:

A. Extension of the generalized modeling process to cover modal choice. This could draw on work recently accomplished by Richards[49/] and the Urban Mass Transportation Administration[50/] and proposed work by the Local Government Operational Research Unit (G.B.)[51/] Recent modeling techniques incorporate more policy sensitive factors to include the effects of changes in parking costs, transit fare structure and travel costs. A generalized

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49/

50/ Urban Mass Transportation Administration, U.S. Department of Transportation

51/ "Research on Transport Demand Models," Proceedings of Fifteenth Annual Meeting, Transportation Research Forum, 1974, p. 354.

modal choice model drawing on the differences between European and the United States experiences in transit development and usage would offer a broad spectrum as a background for assessing the effects of alternative policy decisions.

B. Application of the basic set of trip generation curves across several cities and compare results with known data. This would be a most logical extension to the present subproject. Statistical comparisons could then be made to allow better judgements about the practical application of a generalized trip generation model.

C. Incorporation of system sensitivity in the trip generation process. This would be a logical extension to the current project and an area that would provide a considerable addition to trip generation analysis procedures. System attributes, as input to trip generation, would allow the analyst to address the question of system generated traffic in addition to that which is generated by the land activity alone.

The second broad alternative for further work would include:

A. Additional investigation of national or large regional travel forecasting using the conventional

cross-classification approach. With current concerns over energy consumption and possible restrictions on travel, quick and simple methods of testing alternative proposals are necessary.

B. Application of the TRANS Urban Model System. Procedures are needed that will be capable of assessing alternative mixes and levels of transportation investment. The TRANS approach allows the decision maker to test alternatives to arrive at an "optimum" level of investment in a regional perspective.

APPENDIX A

Variable	NETHERLANDS								ENGLAND				UNITED STATES			
	Randstad Holland	Utrecht	Eindhoven	Zwolle	Leeuwarden	Maastricht	Tilburg	Arnhem	Birmingham (WMTS)	Manchester (SELNEC)	Brentwood	Lincoln	Sioux Falls, South Dakota	Oklahoma City, Okla.	Manchester, New Hampshire	Sacramento, California
I. HOUSEHOLD																
a. Method of collection	1965	1968	Home interview 1970	Interview 1971	Survey 1971	1972	1972	1972	1964	Home interview survey 1966	1966	1970	1963 home interview survey	1965 home interview survey	1964 home interview survey	1968 home interview survey
b. Format									Identified by unique serial number for household information. Repeated on person and trip records				Unique sample no.	Unique sample zone no. comb.	Unique sample no.	Unique sample no.
c. Definition/ coverage	Same as in "European Recommendations for the 1970 Population Census" (Also for pre-1970 surveys)								"One person living alone or a group of persons living together & benefiting from common housekeeping"				Dwelling unit—room or group of rooms occupied or intended for occupancy as separate living quarters by a family or groups of persons living together or by a person living alone.			
1. Sample	30,000 (15%)	25-30%	1,400 (20%)	2,750 (12%)	600 (12%)	3,000 (12%)	6,000 (10%)	20% selected areas	21,000 (2.7%)	25,200	2,786 (18%)	3,800	12%	5.0%	6% in Man. 12% in towns	5.0%
d. Remarks	Samples taken from population registration or from dwelling registration. In latter case all households in sampled D.U. were interviewed.												Combined trip-household records exist		Individual H.H. & trip records	Individual H.H. & trip records
1. Population	Includes Amsterdam, Rotterdam, The Hague, Utrecht 5.3 million pop.	Utrecht & 8 small cities 425,000	Eindhoven & 4 cities 270,000	77,000	90,000	110,000	185,000	250,000	796,000 households	2,500,000	60,000	100,000	83,684	535,000	112,861 includes Manchester & 5 surrounding towns	771,000
II. TRIP																
a. Format	Unlinked trips	Linked trips →							Data coded by individual trip segments (unlinked) on trip tape. Two tapes, weekday & weekend. Income & vehicles avail. on trip rec.	Same as WMTS but data available in linked format	Unlinked trips only. Income & vehicles available on trip records	Linked trips	Trips/household total & by purp. on D.U. summary record. *Linked*		Linked trips on trip record.	Linked trips on trip record
b. Definition/ coverage	A person movement from A to B with one purpose and one mode (foot included). A trip ends when a destination is reached, or when the purpose changes, or when the mode changes. Linked trip is a person movement between two points with one purpose and one or more modes (one of the modes is selected as the major mode).								Includes all modes except walk & bicycle unless they were part of a journey. Includes trips by persons aged *3 or more*	Trips by persons *3 yr. and older* weekday trips	Trips for *all persons* in household	Trips by persons *5 yr. & older* Walk & bicycle incl.	Trips by persons 5 yr. & older →			
	Trips by persons 6 yr. & older	6 yr. & older	5 yr. & older	6 yr. & older	6 yr. & older	6 yr. & older	5 yr. & older	6 yr. & older								
c. Remarks	Data on one record (H.H. + persons + trips) →							3 tapes H.H. per. trips								

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Variable	NETHERLANDS: Randstad Holland (COVW)	Utrecht (KMU)	Eindhoven (VODAR)	Zwolle (IBV)	Leeuwarden (IBV)	Maastricht (IBV)	Tilburg (VODAR)	Arnhem (DHV)	ENGLAND: Birmingham (WMTS)	Manchester (SELNEC)	Brentwood	Lincoln	UNITED STATES: Sioux Falls, South Dakota	Oklahoma City, Okla.	Manchester, New Hampshire	Sacramento, California
III. FAMILY SIZE																
a. Format & definition coverage	Available from home interview survey but location in data and access to it are not evident from material supplied.								Total persons in household irrespective of age given on household information tape. Also, no. of persons 5 yr. & older given. Code 9 = 9 or more persons. (Includes people that come under the definition of household.)				Includes all persons and persons 5 yr. & older. Includes all family members, relatives living in the D.U., lodgers or boarders, servants, college students, persons temporarily away.			
IV. TRIP PURPOSE																
a. Format									Trip origin purpose & destination on trip tape →				Trips by home based and NHB purpose on combined H H. trip record.		Linked trip records exist on tape	Trip records may need to be linked
b. Definition/ coverage	Work at regular work address →								Overall trip purp. not used.		Overall trip purp. not used.					
	Work at other add. firm's business.	Work at other add. & firm's business.	Work at other add., firm's business.	Work at other address & firm's business combined.			Work at other add., firm's business.	Work at other add., firm's business combined.	Home Work Employer's business Shopping (convenience) Shopping (goods) Recreation Social Education Accompanying Serve passenger	Home Work Firm's business School Shopping Pers. business & eat meal Social-recreation Serve passenger Change mode	Home Work In course of work Pers. business Leisure Shop (convenience) Shop (goods) Education Serve passenger Change mode	Home Work Empl. business Pers. business Shopping Social-recreation Education Serve passenger.	Work Personal Business Recreat. School Social Ch. tr. mode Shopping (conv.) Shopping (goods) Serve pass. Home	Work Employment Emp. business Pers. business Recreation School Social Change tr. mode Shopping (conv.) Shopping (goods) Serve pass. Home	Work Personal bus. Recreation School Social Change mode Shop conv. Shop goods Serve pass. Home	Work Related business Home Social or entertainment Recreation Shopping Education Other
	Private business Social visit Shopping School → Recreation → Serve passenger → Medical visit Cultural visit Other	Shop Private visit Carry goods Other	Shop Social visit Private business →	Shop Social visit Carry goods → Other →	Shop Social visit Other	Shop Social visit	Shop social visit Private Business.	Shop Private visit								
V. MODE																
a. Format																
b. Definition/ coverage	Foot → Bicycle → Moped → Motor scooter → Goods vehicle → Motor scooter → Personal auto dr. Personal auto pass. Taxi → Minibus dr. Minibus pass. City bus – TRAM → P.T. bus Other bus → Non P.T. bus Other dr. Other pass.	Goods vehicle Light van dr Light van pass.	Other dr. Other pass.	Minibus dr. → Minibus pass. → Bus → Light van → Other →			P.T. bus Non P.T. Other dr. Other pass.	Light van Goods vehicle City bus Regional bus Other	Coded on trip tape →				Coded on tape →			
									Car driver Car passenger Car pool dr. Bus Rail Taxi Motorcycle Goods vehicle Coach Pedal cycle Walk Other	Car driver Other light vans & motor vehicle driver Car & light van passenger Bus passenger Train passenger Motorcycle dr. Motorcycle pass Other motor veh pass Adult pedal cyclist Walked to work & worked at home	Car & taxi dr. Motorcycle dr. Light van dr. Heavy comm. veh. dr. Passenger in one of above Pedal cycle Walk Bus passenger Other pass. Train pass	Car & light van dr. Car & light van passenger Motorcycle dr. Goods vehicle dr Bus pass. Train pass. Cycle Walk Other	Auto dr. Auto pass. Transit Taxi pass. Truck pass. School bus	Auto dr. Auto pass. Transit Taxi pass. Truck pass. School bus Truck dr. Car pool	Auto dr. Auto pass. Taxi pass. Truck pass. School bus pass. Bus pass.	Auto dr. Taxi dr. Pick-up dr. Truck dr. Auto pass. Taxi pass. Pick-up or truck pass. Public bus pass School bus pass Walk Motorcycle Serve pass Change mode

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Variable	NETHERLANDS								ENGLAND				UNITED STATES			
	Randstad Holland	Utrecht	Eindhoven	Zwolle	Leeuwarden	Maastricht	Tilburg	Arnhem	Birmingham (WMTS)	Manchester (SELNEC)	Brentwood	Lincoln	Sioux Falls, So. Dakota	Oklahoma City, Oklahoma	Manchester, New Hamp.	Sacramento, California
VI. INCOME	The yearly gross income totalled for all members (unless otherwise stated).								All gross income including pensions, benefits, divs., grants, etc.							
	< 6 000 6,000-10 000 10 000-12 000 12,000-18 000 18 000-24,000 > 24,000 (1966 guilders)	None	< 5,000 5,000-10.000 10,000-15 000 15 000-20,000 20,000-25,000 > 25 000 (1970 guilders)	< 8,000 8,000-12,000 12,000-16,000 16,000-24,000 24,000-36,000 > 36,000	→		< 5,000 5,000-10,000 10,000-15,000 15,000-20,000 20,000-25,000 > 25,000 (1972 guilders)	0 < 5,000 5,000-10,000 10,000-15,000 15,000-20,000 20,000-25,000 25,000-30,000 30,000-40,000 40,000-50,000 > 50,000 (1972 guilders)	< 500 500-1,000 1,000-1,500 1,500-2,000 2,000-2,500 2,500-3,000 > 3,000 (1964 pounds)	1-415 416-675 676-935 936-1 195 1,196-1 455 1,456-1 715 1,716-1 975 1,976-2,235 2,236-2,495 2,496-2 755 2,756-3 015 3,016-3 275 3,276-3 535 3,536-3,795 3,796-4 055 > 4,056 (1966 pounds)	0 or no ans < 500 500-999 1,000-1,499 1,500-1,999 2,000-2,999 3,000-3,999 > 4,000 (1966 pounds)	< 500 500-999 1,000-1,499 1,500-1,999 2,000-2,499 2,500-2,999 3,000-3,999 4,000-5,999 > 6,000 (1970 pounds)	<$3,000 3,000-4,999 5,000-6,999 7,000-9,999 10,000-14,999 15,000-24,999 25,000 & +	$0-2,999 3,000-4,999 5,000-6,999 7,000-9,999 10,000 + (1964 $)	$0-1,999 2,000-3,999 4,000-4,999 5,000-5,999 6,000-6,999 7,000-7,999 8,000-9,999 10,000-14,999 15,000-24,999 25,000 & +	< $3,000 3,000-3,999 4,000-4,999 5,000-5,999 6,000-6,999 7,000-7,999 8,000-8,999 9,000-9,999 10,000-12,499 12,500-14,999 15,000-19,999 20,000-24,999 25,000 and +
VII. AUTO OWNERSHIP	Includes personally owned autos plus company cars if they were available to the household outside normal working hours.								Cars owned, hired, loaned by empl.	All cars (4 or 3 wheeled) designed to carry passengers	Cars owned or loaned by empl.		All autos available for personal use to the household incl. company and government owned cars & taxis.			All passenger cars incl taxis, jeeps, station wagons, inf on light trucks & motorcycles also available
VIII. NET RESIDENTIAL DENSITY	Not available from home interview survey. Could be supplied from external sources (eg. density of census area).								Not directly available.				Not directly available. Must be obtained from final reports of study.			
									Net residential density avail. from land use data card deck (pop./acre). Net resi. area & no. of households also on cards.							
IX. WORKERS IN THE HOUSEHOLD	Data available and corresponds to the "International Standard Classification of Occupations."								No. employed persons on household info. tape. Includes persons working > 10 hrs/week.	No. employed persons in H,H, (worked over 30 hrs/week)		No. persons employed 10-30 hr/week > 30 hr/week	No. employed persons given on H.H. tape.	No. unemployed persons given on H.H. tape (code sheet shows no. employed coded also).	No. employed persons in household.	No. employed persons available on household record.

Variable	NETHERLANDS								ENGLAND				UNITED STATES			
	Randstad Holland	Utrecht	Eindhoven	Zwolle	Leeuwarden	Maastricht	Tilburg	Arnhem	Birmingham (WMTS)	Manchester (SELNEC)	Brentwood	Lincoln	Sioux Falls, South Dakota	Oklahoma City, Oklahoma	Manchester, New Hamp.	Sacramento, California
X. STUDENTS	Yes	No	Yes	Yes →				Yes	Student coded under job desc. on person info. tape. (May be hard to use)	Student code under occupation	Not obtainable	?	Occupation & ind. avail. on person records for each H.H. Must be tabulated by H.H. sample no	?	Occupation & industry given on person records for each H.H.	No students available from H.H. record
XI. LOCATION OF HOUSEHOLD	May be obtained from other sources. If 1971 census areas are used a matching with zones would be required, then a sort on the sampled household records by zone might be accomplished.								Would have to be keyed on zone of residence in the household tape records and stratified by groups of zones.				Must be keyed to location of zone of residence found on study area map (Final study reports)			
XII. PERSONS PER AUTO	Not included →								Car occupancy incl driver (coded on trip tape).	Car occupancy coded on trip form.	Car occu- incl. driver (coded on trip tape).	No. of persons 5 yr & older in car coded on trip form.	On trip record (Total persons in car) Auto dr trips only.	Total per in car on trip record for auto driver trips only. Also indicates trip was a car pool	Total persons in car for auto driver trips. Indicates if trip was in a car pool.	Vehicle occupancy available for auto dr trips on trip records

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APPENDIX B

THREE PROGRAMS FOR TRIP GENERATION ANALYSIS USED IN THE TRAVEL FORECASTING SUBPROJECT

GENERAL

Several analytical techniques are important approaches to trip generation analysis. These techniques, cross-classification analysis and dwelling unit regression analysis, offer the analyst more efficient and effective methods for trip end volume estimation as well as convenient tools to monitor and/or update existing trip generation relationships. The overall methodology involved in these functions has been documented previously.[1/] Computer programs, however, have not been readily available to facilitate the use of these techniques.

Three IBM S/360 programs are now available from the Urban Planning Division in the urban transportation planning battery. Two programs (XCLASS and XSOLVE) are directly applicable to the cross-classification technique. The third program (DUSUM) is intended to transform origin-destination survey data into a form that is directly usable as input to either cross-classification or dwelling unit regression analysis.

These programs have been written primarily in FORTRAN IV under Operating System. A 64K machine is adequate in size for operation of each of the programs under normal conditions.

PROGRAM DESCRIPTIONS

DUSUM

This program is designed to merge relevant data from dwelling unit summary records (No. 1 cards) and trip records (No. 2 cards). The resulting output is a dwelling unit record summarizing by sampled dwelling unit any trip and socio-economic information desired. This data set is suitable as

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1/ Federal Highway Administration, Guidelines for Trip Generation Analysis, U.S. Goverment Printing Office, Washington, D.C., June 1967; Fleet, Christopher R., and Robertson, Sydney R., "Trip Generation in the Transportation Planning Process," Highway Research Record No. 240, Highway Research Board, Washington, D.C., 1968, pp. 11-31; Kassoff, H., and Deutschman, H., "Trip Generation: A Critical Appraisal," Highway Research Record No. 297, Highway Research Board, Washington, D.C., 1969, pp. 15-30.

direct input for dwelling unit regression analysis, utilizing, for example, the multiple regression program (BMDO2R)[1/] or the cross-classification analysis program (XCLASS).

The program assumes that both input data sets (dwelling unit and trip cards) are in sort by sample number. Edits are made, however, in both sets for proper sort and the user is warned (1) if either data set is out of sort or (2) if there is no dwelling unit record for a particular trip record.

The user specifies the "from" and "to" purpose codes and the "mode" codes of the trip purposes and modes desired in the dwelling unit summary output. Trips may be summarized by purpose in either origin-destination or production-attraction format, and the output data set may be in either binary (normal) or EBCDIC format, at the option of the user. If combined purposes are desired, then the output of DUSUM may be used with any trans-generation program, such as BMDO9S, which is in the planning battery. Subsequent modifications of this program will allow purpose combination.

Although this program is designed to merge No. 1 and No. 2 cards, other socio-economic and trip data sets may be merged so long as certain constraints are met in describing these data.

XCLASS

This program forms the core of the cross-classification analysis procedures. It provides cross-tabulations, in various forms, of input data based on stratifications of up to three independent variables. Observations in the input data set are assigned to cells of a matrix created by user-specified categories of the two or three independent variables. Cell totals, row and column totals, and a grand total of the number of observations are printed out. If requested by the user, a dependent variable is summed and averaged by cell and printed with row and column totals and averages. Cell standard deviations are also provided. The cell means of the dependent variable can be output for future use in the XSOLVE program (see below) if specified by the user. In the present interim version, only a one-purpose matrix can be created in each run of the program.

The usefulness of XCLASS is paramount in the area of dwelling unit data stratification for developing trip rates by dwelling unit types. It should be emphasized, however, that variables from any data set may be cross-classified using this program.

XSOLVE

This program will provide estimates of trip ends by trip purpose and geographic area designation (e.g., zone) suitable as input for trip distribution programs. Input data consist of a cross-classification matrix

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1/ BMD Biomedical Computer Programs Manual, University of California Press, Berkeley, California.

for each trip purpose (from XCLASS or in punched cards) and socio-economic data (e.g., forecasts) on cards. The socio-economic data are matched with the appropriate cell of the desired trip purpose cross-classification matrix, based on the values of the independent variables in the input data. The program will interpolate between cells if necessary. Trip ends are calculated either from the particular cell value found or from interpolation. If trip end estimates are desired for small geographic areas based on a dwelling unit cross-classification matrix, for example, the total number of dwelling units per area and the proportion of those dwelling units for which the input socio-economic data are representative must be specified. If desired, an average value for the independent variables for each geographic area may be used and a proportional representation of 100 percent would be specified. Output consists of total trips sent and received for all purposes by each geographic area in either production attraction or origin-destination format.

APPENDIX C

I. Purpose

To apply the dwelling unit cross-classification trip generation approach in order to obtain 1995 trip productions by trip purpose for Zone "A".

II. Inputs

A. Independent Variables

1. Forecast mean family income in Zone A for 1995 is $10,000 per household (1968 dollars).
2. Total dwelling units forecast for Zone A in 1995 is 1000.

B. Base year (1968) trip generation relationships.

1. Base year income distribution curves showing percent households by low, medium, and high income ranges (Curve 1).
2. Curves showing percent households stratified by income and auto ownership, based on region-wide data (Curve 2).
3. Curves showing total internal person trips per household stratified by income and auto ownership (Curve 3).
4. Curves showing trip purpose distributions by income (Curve 4).

III. Outputs

A. Total person trip production in Zone "A" in 1995.

B. Person trips by purpose (home-based work, home-based non-work and, non-home based) for 1995.

IV. Procedure

A. Enter income distribution curves (Curve 1) with mean zonal income ($10,000) to estimate the percent of total households in each income category (Low, Medium, High) in zone "A."

B. With the percentages from A above, calculate the number of households in each income category.

C. Enter the auto ownership curves (Curve 2) at the three income levels (use the average income for each category: $5,000, $8,000, $16,000) and determine, for each, the percent households owning 0, 1, and 2 or more cars. (Read to nearest whole percent)

D. Compute the number of households in each car ownership category within each income category. At this point you should have columns 2, 4, and 5 completed:

(1) Income Category	(2) No. of H.H.	(3) Cars/H.H.	(4) % H.H.	(5) No. of H.H.
Low	100	0	22	22
		1	62	62
		2 +	16	16
Medium	550	0	10	55
		1	62	341
		2 +	28	154
High		0	0	0
		1	30	105
		2 +	70	245

E. Enter the trip rate curves (Curve 3) at the three income levels and determine the appropriate total person trips per household by auto ownership level within each income category

F. Calculate total trip productions by car ownership and income category (Column 7) and sum to obtain trips produced within each income group (Column 8).

(1) Income Category	(3) Cars/H.H.	(5) No. of H.H.	(6) Trips/H.H. (from Curve 3)	(7) Total Trips Produced	(8) Trips Produced by Income Category
Low	0	22	4.0	88	808
	1	62	8.0	496	
	2 +	16	14.0	224	
Medium	0	55	6.0	330	6,204
	1	341	10.0	3,410	
	2 +	154	16.0	2,464	
High	0	0	8.0	0	6,160
	1	105	12.0	1,260	
	2 +	245	20.0	4,900	
			TOTAL TRIP PRODUCTIONS =		13,172

G. Enter the trip purpose distribution curves (Curve 4) at each income level to determine the percent of total trips produced by purpose within each income group. (Nearest whole percent)

H. Calculate the total number of trips produced in Zone "A" by purpose within income category. Sum to obtain total estimated trips produced by purpose. Columns 10, 11, and 13 should be completed on next page.

(1) Income Category	(8) Trips Produced by Income Category	(9) Purpose	(10) % Trips by Purpose	(11) Tot. Trips by Purp. & Income	(12) Purpose	(13) Total Trips Prod.
Low	808	HBW	20	162	HBW	1,645
		HBO	60	485		
		NHB	20	162		
Medium	6,204	HBW	14	867	HBO	8,522
		HBO	64	3,971		
		NHB	22	1,365		
High	6,160	HBW	10	616	NHB	3,005
		HBO	66	4,066		
		NHB	24	1,478		
						13,172